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Engine Mechanics; Teaching Methods; Test Items; Units  
of Study

## ABSTRACT

This learning module addresses computers and their applications in contemporary automobiles. The text provides students with information on automotive microcomputers and hands-on activities that will help them see how semiconductors and digital logic devices fit into the modern repair facility. The module contains nine instructional units that cover the following topics: (1) introduction to automotive electronics; (2) safety and accident prevention; (3) automotive DC electronics; (4) semiconductors; (5) digital electronics; (6) automotive microprocessors; (7) computerized engine controls; (8) diagnostic codes and troubleshooting; and (9) automotive microprocessor applications. Each instructional unit follows a standard format that includes some or all of these eight basic components: performance objectives, suggested activities for teachers and students, information sheets, assignment sheets, job sheets, visual aids, tests, and answers to tests and assignment sheets. All of the unit components focus on measurable and observable learning outcomes and are designed for use for more than one lesson or class period. Instructional task analyses; a list of tools, equipment, and materials; and 22 references are also included.  
(KC)

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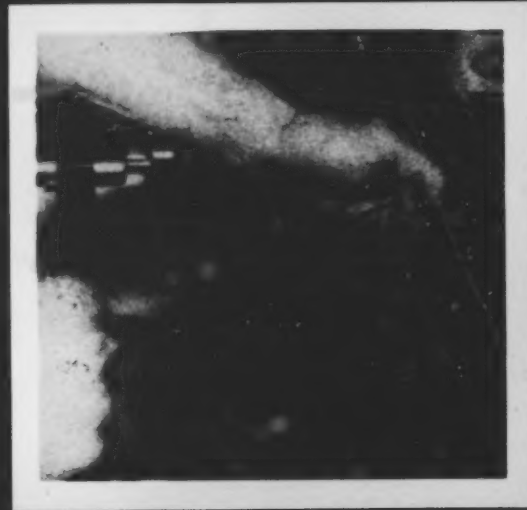
# Automotive Electronics

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**MAVCC**

Teacher Edition





# **AUTOMOTIVE ELECTRONICS**

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and  
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# **AUTOMOTIVE ELECTRONICS**

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## FOREWORD

Automotive microcomputers do marvelous things. One manufacturer has an on-board locator device that uses satellite communications to help a driver pinpoint the vehicle's exact location at any given moment. That application serves to indicate what we can anticipate from on-board automotive computers in the years to come. But computers and cars go far beyond creature comforts and hi-tech gadgetry. Their basic objectives have been to help auto manufacturers comply with federal guidelines for fuel economy and emission controls. These things have already been accomplished, and anyone who drives a computerized vehicle saves money at the gas pump and breathes cleaner air.

The computerized vehicle has also brought changes to the automotive service industry. The service technician of today—and for all the days to come—lives in a world of sensors and the communications links that tie them to command modules. It's a new brand of service that requires not only new troubleshooting techniques, but special test instruments and the skills to use them properly.

*Automotive Electronics* addresses computers and their applications on contemporary automobiles. The text provides students with information and hands-on activities that will help them see how semiconductors and digital logic devices fit into the new scheme of things around a modern repair facility. We think the materials will fulfill an obvious new in automotive programs at all levels, and give students the kind of background they need to stay up with the times.

Harley Schlichting, Chairman  
Board of Directors  
Mid-America Vocational  
Curriculum Consortium

Greg Pierce  
Executive Director  
Mid-America Vocational  
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## ACKNOWLEDGEMENTS

The Resource Committee which planned and approved *Automotive Electronics* was comprised of a choice selection of outstanding auto mechanics instructors and training personnel from General Motors Corporation. To the Resource Committee, we extend a special thank you:

|                        |                                                                                   |
|------------------------|-----------------------------------------------------------------------------------|
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| <b>Arnie Zent</b>      | State Board for Vocational Education, Bismarck, North Dakota                      |
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| <b>Rod Stafford</b>    | Johnson County Community College, Overland Park, Kansas                           |
| <b>Ron Downing</b>     | Lamar AVTS, Lamar, Missouri                                                       |
| <b>Allen Kasperson</b> | Lake Area Vo-Tech School, Watertown, South Dakota                                 |
| <b>Ken Powers</b>      | Vocational Curriculum Development and Research Center,<br>Natchitoches, Louisiana |
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## USE OF THIS PUBLICATION

### Instructional Units

*Automotive Electronics* contains nine units of instruction. Each instructional unit includes some or all of the basic components of a unit of instruction; performance objectives, suggested activities for teachers and students, information sheets, assignment sheets, job sheets, visual aids, tests, and answers to the tests. Units are planned for more than one lesson or class period of instruction.

Careful study of each instructional unit by the teacher will help to determine:

- A. The amount of material that can be covered in each class period
- B. The skills which must be demonstrated
  - 1. Supplies needed
  - 2. Equipment needed
  - 3. Amount of practice needed
  - 4. Amount of class time needed for demonstrations
- C. Supplementary materials such as pamphlets or filmstrips that must be ordered
- D. Resource people who must be contacted

### Objectives

Each unit of instruction is based on performance objectives. These objectives state the goals of the course, thus providing a sense of direction and accomplishment for the student.

Performance objectives are stated in two forms: unit objectives, stating the subject matter to be covered in a unit of instruction; and specific objectives, stating the student performance necessary to reach the unit objective.

Since the objectives of the unit provide direction for the teaching-learning process, it is important for the teacher and students to have a common understanding of the intent of the objectives. A limited number of performance terms have been used in the objectives for this curriculum to assist in promoting the effectiveness of the communication among all individuals using the materials.

Reading of the objectives by the student should be followed by a class discussion to answer any questions concerning performance requirements for each instructional unit.

Teachers should feel free to add objectives which will fit the material to the needs of the students and community. When teachers add objectives, they should remember to supply the needed information, assignment and/or job sheets, and criterion tests.

### **Suggested Activities for the Instructor**

Each unit of instruction has a suggested activities sheet outlining steps to follow in accomplishing specific objectives. Duties of instructors will vary according to the particular unit; however, for best use of the material they should include the following: provide students with objective sheet, information sheet, assignment sheets, and job sheets; preview filmstrips, make transparencies, and arrange for resource materials and people; discuss unit and specific objectives and information sheet; give test. Teachers are encouraged to use any additional instructional activities and teaching methods to aid students in accomplishing the objectives.

### **Information Sheets**

Information sheets provide content essential for meeting the cognitive (knowledge) objectives in the unit. The teacher will find that the information sheets serve as an excellent guide for presenting the background knowledge necessary to develop the skill specified in the unit objective.

Students should read the information sheets before the information is discussed in class. Students may take additional notes on the information sheets.

### **Transparency Masters**

Transparency masters provide information in a special way. The students may see as well as hear the material being presented, thus reinforcing the learning process. Transparencies may present new information or they may reinforce information presented in the information sheets. They are particularly effective when identification is necessary.

Transparencies should be made and placed in the notebook where they will be immediately available for use. Transparencies direct the class's attention to the topic of discussion. They should be left on the screen only when topics shown are under discussion.

### **Assignment Sheets**

Assignment sheets give direction to study and furnish practice for paper and pencil activities to develop the knowledge which is a necessary prerequisite to skill development. These may be given to the student for completion in class or used for homework assignments. Answer sheets are provided which may be used by the student and/or teacher for checking student progress.

### **Job Sheets**

Job sheets are an important segment of each unit. The instructor should be able to demonstrate the skills outlined in the job sheets. Procedures outlined in the job sheets give direction to the skill being taught and allow both student and teacher to check student progress toward the accomplishment of the skill. Job sheets provide a ready outline for students to follow if they have missed a demonstration. Job sheets also furnish potential employers with a picture of the skills being taught and the performances which might reasonably be expected from a person who has had this training.

### **Practical Tests**

Practical tests provide the instructor with an evaluation tool to aid with the documentation of student progress. The tests provide a brief but effective means to determine a student's ability to perform with tools and materials in performing a hands-on process or producing a produce — a vital aid for pinpointing specific areas where students need additional instruction.

### **Test and Evaluation**

Paper-pencil and performance tests have been constructed to measure student achievement of each objective listed in the unit of instruction. Individual test items may be pulled out and used as a short test to determine student achievement of a particular objective. This kind of testing may be used as a daily quiz and will help the teacher spot difficulties being encountered by students in their efforts to accomplish the unit objective. Test items for objectives added by the teacher should be constructed and added to the test.

### **Test Answers**

Test answers are provided for each unit. These may be used by the teacher and/or student for checking student achievement of the objectives.

# **AUTOMOTIVE ELECTRONICS**

## **INSTRUCTIONAL TASK ANALYSIS**

**JOB TRAINING:** What the  
Worker Should Be Able to Do  
(Psychomotor)

**RELATED INFORMATION:** What  
the Worker Should Know  
(Cognitive)

### **UNIT I: INTRODUCTION TO AUTOMOTIVE ELECTRONICS**

1. Terms and definitions
2. The modern automobile
3. Occupational overview
4. Prerequisites for automotive electronics training
5. Training requirements
6. Responsibilities in the workplace
7. Solve basic equations. (Assignment Sheet #1)
8. Solve literal numbers. (Assignment Sheet #2)
9. Interpret a troubleshooting routine from a service manual. (Assignment Sheet #3)

### **UNIT II: SAFETY AND ACCIDENT PREVENTION**

1. Terms and definitions
2. Automotive shop dangers and their causes
3. General shop safety
4. Fire safety
5. Battery safety

**JOB TRAINING: What the  
Worker Should Be Able to Do  
(Psychomotor)**

**RELATED INFORMATION: What  
the Worker Should Know  
(Cognitive)**

6. Steps in safe lifting
7. Ways to recognize shock
8. Steps in treating shock
9. First aid for eye injury
10. Guidelines for first aid emergencies
11. Personal physical and hygiene requirements
12. Service responsibilities
13. Solve safety and accident prevention problems. (Assignment Sheet #1)
14. Complete a student safety pledge. (Assignment Sheet #2)
15. Complete a shop safety drawing. (Assignment Sheet #3)

**UNIT III: AUTOMOTIVE DC ELECTRONICS**

1. Terms and definitions
2. The nature of matter
3. Static electricity
4. Dynamic electricity
5. Batteries
6. Alternators
7. Ohm's law
8. Kirchhoff's law for voltage and current

**JOB TRAINING: What the  
Worker Should Be Able to Do  
(Psychomotor)**

**RELATED INFORMATION: What  
the Worker Should Know  
(Cognitive)**

9. Theories of current flow
10. Series circuits
11. Parallel circuits
12. Series-parallel circuits
13. Voltage measurements
14. Current measurements
15. Resistance measurements
16. Multimeters
17. Linear DC
18. Pulsating DC
19. Conductors
20. Insulators
21. Connectors
22. Fuses
23. Circuit breakers
24. Inductors
25. Capacitors
26. Switches
27. Electromechanical relays
28. Schematic diagrams
29. Scientific notation



**JOB TRAINING: What the  
Worker Should Be Able to Do  
(Psychomotor)**

**RELATED INFORMATION: What  
the Worker Should Know  
(Cognitive)**

30. Troubleshooting an open circuit
31. Troubleshooting a short to ground
32. Troubleshooting shorts into another circuit
33. Troubleshooting high-resistance problems
34. Calculate voltage using Ohm's law. (Assignment Sheet #1)
35. Calculate current flow in amperes using Ohm's law. (Assignment Sheet #2)
36. Calculate resistance using Ohm's law. (Assignment Sheet #3)
37. Measure voltage drops in a series circuit. (Job Sheet #1)
38. Analyze current values in a series circuit. (Job Sheet #2)
39. Measure voltage, current, and resistance in a parallel circuit. (Job Sheet #3)
40. Troubleshoot series-parallel circuits. (Job Sheet #4)

**UNIT IV: SEMICONDUCTORS**

1. Terms and definitions
2. Diode construction
3. Diode action
4. Symbols for other diode types



**JOB TRAINING: What the  
Worker Should Be Able to Do  
(Psychomotor)**

**RELATED INFORMATION: What  
the Worker Should Know  
(Cognitive)**

5. Bipolar transistor structure
6. Transistor operation
7. Transistor applications
8. Field effect transistors
9. Insulated gate FETs
10. Complementary metal oxide FETs
11. Integrated circuits
12. Silicon controlled rectifiers
13. Hall effect devices
14. Rectifier circuits
15. Guidelines for handling static sensitive devices
16. Perform a static test of semiconductor diodes. (Job Sheet #1)
17. Check a hall effect switch for distributor reference signals. (Job Sheet #2)

**UNIT V: DIGITAL ELECTRONICS**

1. Terms and definitions
2. Digital overview
3. Binary digits
4. Logic gates and truth tables
5. The AND gate

**JOB TRAINING: What the  
Worker Should Be Able to Do  
(Psychomotor)**

**RELATED INFORMATION: What  
the Worker Should Know  
(Cognitive)**

6. The OR gate
7. The NOT gate
8. Other basic logic gates
9. D/A converters
10. A/D converters
11. Multiplexing and demultiplexing
12. Fiber optics
13. Complete truth tables for common logic devices. (Assignment Sheet #1)
14. Construct and test an AND gate circuit. (Job Sheet #1)
15. Construct and test an OR gate circuit. (Job Sheet #2)
16. Construct and test a NAND gate circuit. (Job Sheet #3)
17. Construct and test a NOR gate circuit. (Job Sheet #4)
18. Construct and test an EXCLUSIVE-OR gate circuit. (Job Sheet #5)
19. Verify OR gate operation in a cooling fan circuit. (Job Sheet #6)

**JOB TRAINING: What the  
Worker Should Be Able to Do  
(Psychomotor)**

**RELATED INFORMATION: What  
the Worker Should Know  
(Cognitive)**

**UNIT VI: AUTOMOTIVE MICROPROCESSORS**

1. Terms and definitions
2. Computer hardware/software
3. The computer as a decision center
4. How a computer handles input/output
5. Guidelines for handling computers
6. Automotive microprocessor architecture
7. Serial and duplex data communications
8. Other data communications techniques
9. Parallel data communications
10. Transducers and encoders
11. Weather Pack® connectors and locks
12. Microprocessor applications in automotive electronics
13. Remove and replace a PROM using proper grounding protection. (Job Sheet #1)
14. Test integrity of ground and power circuits. (Job Sheet #2)
15. Repair connector terminals. (Job Sheet #3)

**JOB TRAINING: What the  
Worker Should Be Able to Do  
(Psychomotor)**

**RELATED INFORMATION: What  
the Worker Should Know  
(Cognitive)**

**UNIT VII: COMPUTERIZED ENGINE CONTROLS**

1. Terms and definitions
2. Oxygen sensors
3. O<sub>2</sub> sensor operating requirements
4. Manifold absolute pressure sensors
5. Coolant temperature sensors
6. Engine RPM inputs to the CPU
7. Crankshaft position sensors
8. The throttle position sensor
9. Manifold air temperature sensors
10. Mass-air flow sensors
11. Input sensor interaction
12. System output controls
13. Pulse width and on time functions
14. Fuel control systems
15. Ignition spark timing control
16. Exhaust gas recirculation controls
17. Emission control devices
18. Test oxygen sensor operations. (Job Sheet #1)
19. Test MAP sensor functions. (Job Sheet #2)

**JOB TRAINING: What the  
Worker Should Be Able to Do  
(Psychomotor)**

**RELATED INFORMATION: What  
the Worker Should Know  
(Cognitive)**

20. Test engine coolant temperature sensor operations. (Job Sheet #3)
21. Test TPS operations. (Job Sheet #4)
22. Test EGR valve operations. (Job Sheet #5)
23. Adjust ignition timing. (Job Sheet #6)

**UNIT VIII: DIAGNOSTIC CODES AND TROUBLESHOOTING**

1. Terms and definitions
2. Troubleshooting guidelines
3. Troubleshooting lean/rich fuel conditions
4. Troubleshooting trees
5. Guidelines for testing wiring
6. Retrieving Chrysler diagnostic codes
7. Retrieving General Motors diagnostic codes
8. Retrieving Ford diagnostic codes
9. Hand held scanning devices
10. Guidelines for using hand held scanners
11. Code setting parameters

**JOB TRAINING: What the  
Worker Should Be Able to Do  
(Psychomotor)**

**RELATED INFORMATION: What  
the Worker Should Know  
(Cognitive)**

12. Identify operational systems and sensors, and list diagnostic codes for a Chrysler vehicle. (Assignment Sheet #1)
13. Identify operational systems and sensors, and list diagnostic codes for a General Motors vehicle. (Assignment Sheet #2)
14. Identify operational systems and sensors, and list diagnostic codes for a Ford vehicle. (Assignment Sheet #3)
15. Retrieve Chrysler diagnostic codes manually, and with a scanner. (Job Sheet #1)
16. Retrieve General Motors diagnostic codes manually, and with a scanner. (Job Sheet #2)
17. Retrieve Ford diagnostic codes manually, and with a scanner. (Job Sheet #3)

**UNIT IX: AUTOMOTIVE MICROPROCESSOR APPLICATIONS**

1. Terms and definitions
2. Dashboard functions
3. Anti-lock brake controls
4. Seat position controls
5. Steering controls
6. Suspension controls
7. Keyless entry

**JOB TRAINING: What the  
Worker Should Be Able to Do  
(Psychomotor)**

**RELATED INFORMATION: What  
the Worker Should Know  
(Cognitive)**

8. Theft deterrent systems
  9. Trip control/monitor systems
  10. Cruise control
  11. Electronic climate control
  12. Voice alert systems
  13. Other control systems
- 
14. Identify Chrysler computer applications for operator comfort and safety. (Assignment Sheet #1)
  15. Identify General Motors computer applications for operator comfort and safety. (Assignment Sheet #2)
  16. Identify Ford computer applications for operator comfort and safety. (Assignment Sheet #3)

## **AUTOMOTIVE ELECTRONICS**

### **TOOLS, EQUIPMENT, AND MATERIALS LIST**

Basic hand tools  
Basic shop tools  
Basic safety equipment and supplies  
0 to 12 volt power supply  
Power supply capable of 120V DC  
1.5V battery  
Resistor assortment, 50 to 470 ohm  
Diode assortment  
LED assortment  
Electrical breadboard  
Proto board for IC connections  
SN7411 triple 3-input positive AND gate  
SN7432 quadruple 2-input positive OR gate  
SN7400 quadruple 2-input positive NAND gate  
SN 7402 quadruple 2-input NOR gate  
SN7485 quadruple 2-input Exclusive OR gate  
Ground clip  
IC extractor  
Wire repair kit with terminal removing tools  
Jumper leads (16 gauge wire)  
Hand held vacuum pump and gauge w/vacuum tee  
Watch with second hand  
Pocket knife  
Scanners for retrieving diagnostic codes  
(ALCL scanner for Chevrolet, Ford Rotunda, Chrysler DRB II, or OTC Monitor 2000 equivalent)



## AUTOMOTIVE ELECTRONICS

### REFERENCES

- A. Bignell, James and Robert Donovan. *Digital Electronics*. Albany, NY 12212: Delmar Publishers, Inc., 1985.
- B. Cave and Terrell. *Digital Technology with Microprocessors*. Reston, VA: Reston Publishing Co., Inc. 1981.
- C. *EEC III EEC IV 5-DAY TECHNICIAN CERTIFICATION*. Dearborn, MI 48121: Ford Parts and Service Division, Training and Publications Department, 1985.
- D. *Electricity and Electronics, Fundamentals*. Highland Park, MI 48203: Service Training, Chrysler Corporation, 1984.
- E. Floyd, Thomas L. *Digital Fundamentals*, Second Edition. Columbus, OH: Charles E. Merrill Co., 1982.
- F. *Fundamentals of Electronics and Semiconductors*. Benton Harbor, MI: Heath Company, 1985.
- G. Harwick, Jim. *General Industrial Electronics*. Stillwater, OK: Oklahoma Curriculum and Instructional Materials Center, 1984.
- H. *Kansas Safety Education Handbook, Volume III*. Wichita, KS: Kansas State Department of Education in cooperation with Wichita Public Schools, U.S.D. 259, 1981.
- I. Kidde Portable Extinguishers, *The ABC's of Fire Prevention*. Belleville, NJ: Walter Kidde & Co., Inc., 1978.
- J. Malvino, Albert P. *Digital Computer Electronics*, Second Edition. New York: McGraw-Hill Book Co., 1983.
- K. *OSHA Safety and Health Standards (29 CFR 1910), Revised*. Washington, DC 20402: U.S. Department of Labor, Occupational Safety and Health Administration, 1981.
- L. Rutkowski, George B. and Olesky, Jerome E. *Fundamentals of Digital Electronics*. Englewood Cliffs, NJ: Prentice-Hall, Inc., 1985.
- M. *Servicing Vehicle Electronic Instruments*. Dearborn, MI 48121: Ford Parts and Service Division, Training and Publications Department, 1985.
- N. *Specialized Electronics Training*. Warren, MI 48090: Product Service Training, General Motors Corporation, 1984.
- O. The American Red Cross, *Standard First Aid and Personal Safety*. Garden City, NY: Doubleday and Co., Inc. 1978.
- P. *Tools and Techniques, Chrysler Computerized Engine Controls Through 1985*. Owatonna, MN 55060: Mitchell Information Services, Inc., 1985.

- Q. *Tools and Techniques, Ford MCU and EEC-IV, Computerized Engine Controls Through 1985.* Owatona, MN 55060: Mitchell Information Services, Inc. 1985.
- R. *Tools and Techniques, General Motors Computerized Engine Controls Through 1985.* Owatona, MN 55060: Mitchell Information Services, Inc., 1985.
- S. Willison, Neal and James Shelton. *Basic Electronics II.* Stillwater, OK: Mid-America Vocational Curriculum Consortium, 1981.
- T. *1987 Service Manual, Electrical, Fuel, & Emissions, Front Wheel Drive Car, Omni/Charger, Horizon/Turismo, Aries, Reliant, Daytona, LeBaron, New Yorker, 600, Caravelle, Lancer, LeBaron GTS, Shadow, Sundance.* Highland Park, MI 48203: Chrysler Corporation, 1986.
- U. *1988 Chevrolet Camaro Service Manual.* Detroit, MI: General Motors Corporation, 1987.
- V. *1988 Ford Car Shop Manual, Body/Chassis/Electrical, Taurus/Sable.* Dearborn, MI 48121: Ford Motor Company, 1987.



## INTRODUCTION TO AUTOMOTIVE ELECTRONICS UNIT I

### UNIT OBJECTIVE

After completion of this unit, the student should be able to discuss present and future trends in automobile design, and the role of microcomputers in automobiles. The student should also be able to list personal requirements for an automotive electronics technician, training required, and solve basic math problems. These competencies will be evidenced by correctly performing the procedures outlined in the assignment sheets and by scoring a minimum of 85 percent on the unit test.

### SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms related to automotive electronics with their correct definitions.
2. Complete statements concerning the modern automobile.
3. Select true statements concerning occupational overview.
4. Complete statements concerning prerequisites for automotive electronics training.
5. Complete statements concerning the training requirements.
6. Complete statements concerning responsibilities in the workplace.
7. Solve basic equations. (Assignment Sheet #1)
8. Solve literal numbers. (Assignment Sheet #2)
9. Interpret a troubleshooting routine from a service manual. (Assignment Sheet #3)

## INTRODUCTION TO AUTOMOTIVE ELECTRONICS UNIT I

### SUGGESTED ACTIVITIES

- A. Provide students with objective sheet.
- B. Provide students with information and assignment sheets.
- C. Make transparencies.
- D. Discuss unit and specific objectives.
- E. Discuss information sheet.
- F. Invite an industry representative to speak to the class about the field of automotive electronics.
- G. Have students visit a service center and talk to people working in automotive electronics.
- H. Have students prepare a written summary of their visit and talks with people in industry.
- I. Have students give a brief oral report about their visit.
- J. Conduct a tour of the school facilities to acquaint students with the total school environment and places like the counselor's office, break rooms, and other special areas the student should know how to find.
- K. Outline rules of conduct expected in your area.
- L. Plan ahead for Unit VII, "Computerized Engine Controls." Fram's SHOP TALK series includes a 60-minute video tape covering "Computerized Engine Controls." For information about pricing and the complete package, write:  
Fram Division  
Allied Automotive  
SHOP TALK  
105 Pawtucket Avenue  
East Providence, RI 02916
- M. Another valuable training aid is available from Sun Electronic Corporation. Sun's 1985 Edition Computerized Engine Controls, Diagnosis and Testing, covers foreign cars, both Japanese and European, that are not covered in this text. Information is available from:  
Sun Electric Corporation  
One Sun Parkway  
Crystal Lake, IL 60014
- N. Give test.

## REFERENCES USED IN DEVELOPING THIS UNIT

- A. *EEC III EEC IV 5-DAY TECHNICIAN CERTIFICATION*. Dearborn, MI 48121: Ford Parts and Service Division, Training and Publications Department, 1985.
- B. *Specialized Electronics Training*. Warren, MI 48090: Product Service Training, General Motors Corporation, 1984.
- C. *Electricity and Electronics, Fundamentals*. Highland Park, MI 48203: Service Training, Chrysler Corporation, 1984.

# INTRODUCTION TO AUTOMOTIVE ELECTRONICS

## UNIT I

### INFORMATION SHEET

#### I. Terms and definitions

- A. AC — Alternating current
- B. DC — Direct current
- C. IC — Integrated circuit, a technology that packages complex electronic circuits on small silicon chips
- D. Microprocessor — A complex computer circuit built using integrated circuit technology
- E. Microcomputer — A complete computer made up of integrated circuit components

#### II. The modern automobile

- A. Following World War II, America quickly became a country on wheels, and as the number of vehicles on American highways increased, so did the quantity of dangerous hydrocarbons and lead in automotive emissions.
- B. Lead free gas was introduced in the late 1960's to help clean up the environment, but it took the oil crisis of 1973 to inspire the move to better engine design to accomplish fuel efficiency and control emissions.
- C. Government regulations set up a time table for manufacturers to meet requirements for safety, for improved mileage, and for emissions control.
- D. The traditional vacuum/mechanical controls on cars gave way to lighter weight, more accurate electronic controls, and computerized engine controls became an important element in the modern automobile.
- E. The current trend is toward the use of multiple computers to control everything from fuel consumption to passenger comfort, and improvements will continue to be rapid and dramatic.
- F. An indication of industry's commitment to automotive computers is evidenced by the fact that General Motors is the world's largest manufacturer of microcomputers.

#### III. Occupational overview

- A. As high-tech automobiles become the norm on American highways, technicians with high-tech skills will be needed to service them.

## INFORMATION SHEET

- B. Automotive computer electronics will become the most important area of automotive service, not only on new automobiles, but on used cars, too.
- C. Although the stress will be on computer systems service, a good technician will still need training in basic automotive systems.
- D. The good technician will also develop skills in digital electronics and micro-computer electronics as they apply to the automobile.
- E. Technicians who can service automotive computer systems will be well rewarded in the workplace because they will be at skill level "A" which means they will be the best paid technicians in the automotive service industry.
- F. For the automotive electronics technician who has well rounded skills in other service areas, advancement usually comes quickly:
  - 1. Service manager
  - 2. Independent shop owner
  - 3. Instructor in a school or service center

### IV. Prerequisites for automotive electronics training

- A. Technicians should have good math skills:
  - 1. The ability to add, subtract, and multiply equations (Transparency 1)
  - 2. The ability to use literal numbers to express relationships (Transparency 2)
  - 3. The ability to manipulate equations (Transparency 3)
  - 4. The ability to reduce equations to simplest form (Transparency 4)
  - 5. The ability to divide a quantity by itself (Transparency 5)
  - 6. The ability to solve equations (Transparency 6)
- B. Automotive electronics technicians must have good reading comprehension because they will have to properly interpret technical manuals and schematic diagrams.
- C. Automotive electronics technicians must have good communication skills because they will be discussing technical problems with other technicians and customers.



## INFORMATION SHEET

- D. Basic typing skills are useful to the technician because some test instruments require reprogramming from time to time on computer keyboards.

### V. Training requirements

- A. Automotive electronic technicians should also be trained in a comprehensive auto mechanics course.
- B. A background in automotive mechanics will help a technician better understand how a microcomputer controls an automotive system.
- C. Computers are not the only things that go wrong with automobiles and being able to accomplish standard automobile repair will be required of well-rounded technicians.

- D. Automotive electronics technicians should also be trained in:

- 1. Automotive DC electronics

- (NOTE: DC electronics includes the study of circuits, voltage, current, and resistance, the use of test instruments, and the study of power sources.)

- 2. Automotive AC electronics

- (NOTE: AC electronics includes the study of magnetism, electromagnetism, inductors, and capacitors, and should also include AC circuit characteristics, solenoids, relays, and sine wave generation.)

- 3. The oscilloscope and how to use it should be emphasized as part of the training.

- 4. Semiconductors

- (NOTE: This should cover diodes, transistors, integrated circuits or IC's, as well as zener diodes, Hall effect generators, and electrostatic discharge control.)

- 5. Digital electronics

- (NOTE: This should include basic BIT definition, basic logic gates, analog to digital converters and digital to analog converters, multiplexing, demultiplexing, and a brief overview of fiber optics.)

- 6. Automotive microprocessors

- (NOTE: This should include microprocessor architecture including bus structure, input/output data transfer, and applications of microcomputers in automobiles.)



## INFORMATION SHEET

7. Computerized engine controls including sensor inputs, controller outputs, and test equipment
8. System microcomputer controls for systems outside the engine
9. Sensor testing, system operation, and troubleshooting for each system

### VI. Responsibilities in the workplace

- A. Be dependable and get to work on time.
- B. Be neat and clean.
- C. Be sensible enough to ask questions when you need to.
- D. Be right the first time you do a job because comebacks increase shop costs, displease management, and irritate customers.
- E. Be respectful of tools and test instruments and keep the shop area clean.
- F. Be safety conscious at all times.

# Equations



## BALANCE

We can add, subtract, multiply, or divide one side of the equation—as long as we do the same to the other side to keep the balance.

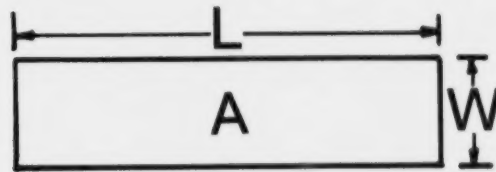
if:  $3x = 2y$

then:  $3x + 3 = 2y + 3$  is equal

and:  $\frac{3x + 3}{2} = \frac{2y + 3}{2}$  is also equal

## Literal Numbers

LITERAL NUMBERS ARE USED TO  
SHOW RELATIONSHIPS



AREA (A) = LENGTH (L) x WIDTH (W)

THIS RELATIONSHIP IS TRUE FOR  
ANY RECTANGLE

$$A = L \times W$$

## Manipulating Equations

$$A = L \times W$$

Solve For W:

$$A = L \times W$$

$$\frac{A}{L} = \frac{L \times W}{L}$$

Recall That Any Quantity Divided By  
Itself = 1;  $\frac{J}{J} = 1$

$$\frac{A}{L} = \frac{L \times W}{L}$$

1 ↖

So:

$$\frac{A}{L} = W$$

## Reducing an Equation to Simplest Form

$$X = 6 \times (2 + 3) \qquad X = \underline{\hspace{2cm}}$$

The Operation Within The ( ) Is Completed *First*.

$$X = 6 \times (5)$$

$$\underline{X = 30}$$

## Dividing a Quantity by Itself

$$Z = (6 + 4) / (5 + 3 + 2)$$

$$Z = (10) / (10)$$

$$\underline{Z = 1}$$

Any Quantity Divided By Itself Is One.

# Solving Equations

$$I \times E = W \qquad E = \underline{\hspace{2cm}}$$

Divide Both Sides Of The Equation By I

$$\frac{I \times E}{I} = \frac{W}{I}$$

Look For Ones

$$\overset{I}{\cancel{I}} \times E = \frac{W}{\cancel{I}}$$

$$\underline{E = \frac{W}{I}}$$

## INTRODUCTION TO AUTOMOTIVE ELECTRONICS UNIT I

### ASSIGNMENT SHEET #1 — SOLVE BASIC EQUATIONS

Your Name \_\_\_\_\_

Date \_\_\_\_\_

Directions: Solve each of the following equations.

1.  $X = 3 + 2$   $X =$  \_\_\_\_\_

2.  $X = 6 \times 2 + 3$   $X =$  \_\_\_\_\_

3.  $X = 6 \times (2 + 3)$   $X =$  \_\_\_\_\_

4.  $Y = (6 + 2) \times 2$   $Y =$  \_\_\_\_\_

5.  $Y = 8 \div 4 + 5$   $Y =$  \_\_\_\_\_

6.  $Y = 9 \div (5 + 4)$   $Y =$  \_\_\_\_\_

7.  $Z = (6 + 4) \div (5 + 3 + 2)$   $Z =$  \_\_\_\_\_

8.  $Z = 3^2 + 3$   $Z =$  \_\_\_\_\_

9.  $Z = 4^2 \div 2^4$   $Z =$  \_\_\_\_\_

10.  $3 + 2 \times 4 = Y$   $Y =$  \_\_\_\_\_



## INTRODUCTION TO AUTOMOTIVE ELECTRONICS UNIT I

### ASSIGNMENT SHEET #2 — SOLVE LITERAL NUMBER EQUATIONS

Your Name \_\_\_\_\_

Date \_\_\_\_\_

Directions: Solve each of the following equations for the literal number indicated.

1.  $E = I \times R$

$R = \underline{\hspace{2cm}}$

2.  $E = I \times R$

$I = \underline{\hspace{2cm}}$

3.  $R = E \div I$

$E = \underline{\hspace{2cm}}$

4.  $R = E \div I$

$I = \underline{\hspace{2cm}}$

5.  $RI = E$

$I = \underline{\hspace{2cm}}$

6.  $Z = Z \div R$

$R = \underline{\hspace{2cm}}$

7.  $W = I^2R$

$R = \underline{\hspace{2cm}}$

8.  $W = I^2R$

$I = \underline{\hspace{2cm}}$

9.  $I \times E = W$

$E = \underline{\hspace{2cm}}$

10.  $R_T = (R_1 \times R_2) \div (R_1 + R_2)$

$R_1 = \underline{\hspace{2cm}}$

## INTRODUCTION TO AUTOMOTIVE ELECTRONICS UNIT I

### ASSIGNMENT SHEET #3 — INTERPRET A TROUBLESHOOTING ROUTINE

Your Name\_\_\_\_\_

Date\_\_\_\_\_

Directions: Your instructor will provide you with a service manual for a specific year, model, and make automobile. Read the introductory materials in the service manual, and then select a troubleshooting routine related to a microcomputer function on the automobile. Write down the routine in your own words, and turn it in to your instructor. Use the following suggestions as guidelines for your report.

1. Does the routine require retrieving a diagnostic or trouble code?
2. Does the routine require clearing a diagnostic or trouble code?
3. What special equipment, if any, does the routine require?
4. Should the routine be accomplished with the key ON or OFF?
5. Should the routine be accomplished with the engine cold or at normal operating temperature?
6. What safety precautions must be exercised while performing the routine?
7. Is the routine a general routine, or is it a routine that directly reflects a customer complaint or a specific problem?
8. Does the routine require preliminary troubleshooting or special preparations?
9. Does the routine move systematically to isolate a problem?

## INTRODUCTION TO AUTOMOTIVE ELECTRONICS UNIT I

### ANSWERS TO ASSIGNMENT SHEETS #1

#### Assignment Sheet #1

1.  $X = 5$
2.  $X = 15$
3.  $X = 30$
4.  $Y = 16$
5.  $Y = 7$
6.  $Y = 1$
7.  $Z = 1$
8.  $Z = 12$
9.  $Z = 1$
10.  $Y = 11$

#### Assignment Sheet #2

1.  $R = E \div I$
2.  $I = E \div R$
3.  $E = R \times I$
4.  $I = E \div R$
5.  $I = E \div R$
6.  $R = 1$
7.  $R = W \div I^2$
8.  $I = (W \div R)^{1/2}$
9.  $E = W \div I$
10.  $R_1 = (R_1 \times R_2) \div (R_2 - R_1)$

#### Assignment Sheet #3

Evaluated to the satisfaction of the instructor.

# INTRODUCTION TO AUTOMOTIVE ELECTRONICS

## UNIT I

NAME \_\_\_\_\_

### TEST

1. Match the terms on the right with their correct definitions.

|          |                                                                                                   |                   |
|----------|---------------------------------------------------------------------------------------------------|-------------------|
| _____ a. | Alternating current                                                                               | 1. DC             |
| _____ b. | Direct current                                                                                    | 2. AC             |
| _____ c. | Integrated circuit, a technology that packages complex electronic circuits on small silicon chips | 3. Microprocessor |
|          |                                                                                                   | 4. Microcomputer  |
| _____ d. | A complex computer circuit built using integrated circuit technology                              | 5. IC             |
| _____ e. | A complete computer made up of integrated circuit components                                      |                   |

2. Complete statements concerning the modern automobile by inserting the word(s) or figure(s) that best complete each statement.

- a. Following World War II, America quickly became a country on wheels, and as the number of vehicles on American highways increased, so did the quantity of dangerous \_\_\_\_\_ and \_\_\_\_\_ in automotive emissions.
- b. Lead free gas was introduced in the late \_\_\_\_\_ to help clean up the environment, but it took the \_\_\_\_\_ crisis of 1973 to inspire the move to better engine control emissions.
- c. Government regulations set up a \_\_\_\_\_ \_\_\_\_\_ for manufacturers to meet requirements for safety, for improved mileage, and for emissions control.
- d. The traditional \_\_\_\_\_ / \_\_\_\_\_ controls on cars gave way to lighter weight, more accurate electronic controls, and computerized engine controls became an important element in the modern automobile.
- e. The current trend is toward the use of \_\_\_\_\_ \_\_\_\_\_ to control everything from fuel consumption to passenger comfort, and improvements will continue to be rapid and dramatic.
- f. An indication of industry's commitment to automotive computers is evidenced by the fact that \_\_\_\_\_ \_\_\_\_\_ is the world's largest manufacturer of microcomputers.

## TEST

3. Select true statements concerning occupational overview by placing an "X" beside each statement that is true.

(NOTE: For a statement to be true, all parts of the statement must be true.)

- \_\_\_\_\_ a. As high-tech automobiles become the norm on American highways, technicians with high-tech skills will be needed to service them.
- \_\_\_\_\_ b. Automotive computer electronics will become the most important area of automotive service, but only on new automobiles.
- \_\_\_\_\_ c. Although the stress will be on computer systems service, a good technician will still need training in basic automotive systems.
- \_\_\_\_\_ d. The good technician will also develop skills in digital electronics and microcomputer electronics as they apply to the automobile.
- \_\_\_\_\_ e. Technicians who can service automotive computer systems will be well rewarded in the workplace because they will be at skill level "A" which means they will be the best paid technicians in the automotive service industry.
- \_\_\_\_\_ f. For the automotive electronics technician who has well rounded skills in other service areas, advancement usually comes quickly:
  - 1) Service manager
  - 2) Independent shade tree mechanic
  - 3) Instructor in a school or service center

4. Complete statements concerning prerequisites for automotive electronics training by inserting the word(s) that best complete each statement.

- a. Technicians should have good \_\_\_\_\_ skills:
  - 1) The ability to add, subtract, and multiply \_\_\_\_\_
  - 2) The ability to use \_\_\_\_\_ numbers to express relationships
  - 3) The ability to manipulate \_\_\_\_\_
  - 4) The ability to reduce equations to \_\_\_\_\_ form
  - 5) The ability to divide a quantity by \_\_\_\_\_
  - 6) The ability to \_\_\_\_\_ equations
- b. Automotive electronics technicians must have good \_\_\_\_\_ comprehension because they will have to properly interpret technical manuals and \_\_\_\_\_ diagrams.

## TEST

- c. Automotive electronics technicians must have good communication skills because they will be discussing technical problems with other technicians and \_\_\_\_\_.
  - d. Basic \_\_\_\_\_ skills are useful to the technician because some test instruments require reprogramming from time to time on computer keyboards.
5. Complete statements concerning training requirements by inserting the word(s) that best completes each statement.
- a. Automotive electronic technicians should also be trained in a comprehensive \_\_\_\_\_ course.
  - b. A background in automotive mechanics will help a technician better understand how a \_\_\_\_\_ controls an automotive system.
  - c. Computers are not the only things that go \_\_\_\_\_ with automobiles and being able to accomplish standard automobile repair will be required of well-rounded technicians.
  - d. Automotive electronics technicians should also be trained in:
    - 1) Automotive \_\_\_\_\_ electronics
    - 2) Automotive \_\_\_\_\_ electronics
    - 3) The \_\_\_\_\_ and how to use it should be emphasized as part of the training
    - 4) \_\_\_\_\_
    - 5) \_\_\_\_\_ electronics
    - 6) Automotive \_\_\_\_\_
    - 7) Computerized \_\_\_\_\_ controls including sensor inputs, controller outputs, and test equipment
    - 8) System microcomputer controls for systems outside the \_\_\_\_\_
    - 9) Sensor testing, system operation, and \_\_\_\_\_ for each system
6. Complete statements concerning responsibilities in the workplace by inserting the word(s) that best complete each statement.
- a. Be \_\_\_\_\_, and get to work on time.
  - b. Be neat and \_\_\_\_\_.

**TEST**

- c. Be sensible enough to \_\_\_\_\_ when you need to.
- d. Be right the first time you do a job because comebacks increase shop \_\_\_\_\_, displease management, and irritate customers.
- e. Be respectful of \_\_\_\_\_ and \_\_\_\_\_ and keep the shop area clean.
- f. Be \_\_\_\_\_ conscious at all times.

(NOTE: If the following activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

- 7. Solve basic equations. (Assignment Sheet #1)
- 8. Solve literal numbers. (Assignment Sheet #2)
- 9. Interpret a troubleshooting routine from a service manual. (Assignment Sheet #3)

## INTRODUCTION TO AUTOMOTIVE ELECTRONICS UNIT I

### ANSWERS TO TEST

1.
  - a. 2
  - b. 1
  - c. 5
  - d. 3
  - e. 4
2.
  - a. Hydrocarbons, lead
  - b. 1960's, oil
  - c. Time table
  - d. Vacuum/mechanical
  - e. Multiple computers
  - f. General Motors
3. a, c, d, e, f
4.
  - a. Math
    - 1) Equations
    - 2) Literal
    - 3) Equations
    - 4) Simplest
    - 5) Itself
    - 6) Solve
  - b. Reading, schematic
  - c. Customers
  - d. Typing
5.
  - a. Auto mechanics
  - b. Microcomputer
  - c. Wrong
  - d.
    - 1) DC
    - 2) AC
    - 3) Oscilloscope
    - 4) Semiconductors
    - 5) Digital
    - 6) Microprocessors
    - 7) Engine
    - 8) Engine
    - 9) Troubleshooting
6.
  - a. Dependable
  - b. Clean
  - c. Ask questions
  - d. Costs
  - e. Tools, test equipment
  - f. Safety



**ANSWERS TO TEST**

7. Evaluated to the satisfaction of the instructor
8. Evaluated to the satisfaction of the instructor
9. Evaluated to the satisfaction of the instructor



## SAFETY AND ACCIDENT PREVENTION UNIT II

### UNIT OBJECTIVE

After completion of this unit, the student should be able to discuss automotive shop dangers, and general shop safety. The student should also be able to list rules for fire safety, battery safety, and safe lifting, and solve problems related to safety and accident prevention. These competencies will be evidenced by correctly completing the procedures outlined in the assignment sheets, and by scoring a minimum of 100 percent on the unit test.

### SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms related to safety and accident prevention with their correct definitions.
2. Match automotive shop dangers with their causes.
3. Select true statements concerning general shop safety.
4. Solve problems concerning fire safety.
5. Complete statements concerning battery safety.
6. Arrange in order the steps in safe lifting.
7. Select true statements concerning ways to recognize shock.
8. Arrange in order the steps in treating shock.
9. Complete statements concerning first aid for eye injury.
10. Select true statements concerning general guidelines for first aid emergencies.
11. Solve problems concerning personal physical and hygiene requirements.
12. Complete statements concerning service responsibilities.
13. Solve safety and accident prevention problems. (Assignment Sheet #1)
14. Complete a student safety pledge. (Assignment Sheet #2)
15. Complete a shop safety drawing. (Assignment Sheet #3)

## **SAFETY AND ACCIDENT PREVENTION UNIT II**

### **SUGGESTED ACTIVITIES**

- A. Provide students with objective sheet.
- B. Provide students with information and assignment sheets.
- C. Make transparency.
- D. Discuss unit and specific objectives.
- E. Discuss information and assignment sheets.
- F. Discuss safety rules that apply to classroom conduct, the proper and authorized use of tools and equipment, school requirements for student insurance, and the reasons for a student safety pledge.
- G. Invite the local fire department to give a fire fighting demonstration and give a fire safety talk. Include a demonstration of proper use of fire extinguishers in the shop and classroom areas.
- H. Demonstrate the proper procedure for dealing with an automotive electrical fire.
- I. Discuss the fire evacuation plan for classroom and shop, evacuation routes and fire exits, after-emergency assembly points, and procedures for tornado alerts.
- J. Invite a local red cross instructor or another instructor certified to teach first aid to talk to the class about emergency first aid procedures, especially those procedures related to proper use of the eye flush station, treating cuts, puncture wounds, and burns.
- K. Invite a certified first aid instructor to demonstrate the use of pressure points to control bleeding and the use of cardiopulmonary resuscitation (CPR).
- L. Demonstrate the proper method of blocking an automobile before jacking up.
- M. Demonstrate the proper use of a hydraulic lift.
- N. Demonstrate proper jump-starting procedure to reduce the risk of battery explosion.
- O. Give test.

## REFERENCES USED IN DEVELOPING THIS UNIT

- A. The American Red Cross, *Standard First Aid and Personal Safety*. Garden City, NY: Doubleday and Co., Inc., 1978.
- B. *Kansas Safety Education Handbook, Volume III*. Wichita, KS: Kansas State Department of Education in cooperation with Wichita Public Schools, U.S.D. 259, 1981.
- C. Kidde Portable Extinguishers, *The ABC's of Fire Prevention*. Belleville, NJ: Walter Kidde & Co., Inc., 1978.
- D. OSHA *Safety and Health Standards (29 CFR 1910), Revised*. Washington, D.C. 20402: U.S. Department of labor, Occupational Safety and Health Administration, 1981.

## **SAFETY AND ACCIDENT PREVENTION UNIT II**

### **INFORMATION SHEET**

#### **I. Terms and definitions**

- A. Safety — State or condition of being safe; freedom from danger, risk, or injury
- B. Accident — Any suddenly occurring, unintentional event which causes personal injury or property damage
- C. First aid — Immediate, temporary care given the victim of an accident or sudden illness until the service of a physician can be obtained
- D. Combustibles — Materials or liquids that catch fire easily
- E. Hygiene — The science of good health and its maintenance, including sanitary practice and cleanliness

#### **II. Automotive shop dangers and their causes**

- A. Exhaust gas inhalation — Caused by running engines in a shop without properly removing exhaust gases
- B. Explosions and fire — Caused by charging batteries in improperly ventilated areas, use of improper cleaning agents, and careless use of drop lights and welding/cutting equipment
- C. Back injury — Almost always caused by improper lifting, and workers compensation records in almost every state indicate that back injuries and related problems are the number one cause of lost work time
- D. Eye injury — Almost always caused by failure to wear safety glasses or a face shield
- E. Cuts and bruises — Caused by improperly using tools, failure to wear gloves or other protective clothing, and careless housekeeping that causes trips and falls
- F. Bodily injury — Caused by improper or careless use of jacks and lifts, and wearing improper clothing around moving or rotating equipment

#### **III. General shop safety**

- A. Operate power lifts according to manufacturers' directions, and make sure the descent area is clear before lowering a power lift.

## INFORMATION SHEET

- B. Use jack stands to secure a vehicle when you have to work under it, and remember that a jack handle sticking out into a walkway is a tripping hazard.
- C. Remove ties, rings, and jewelry when working in the shop, and confine long hair, especially when working around rotating parts.
- D. Keep hands free of fan blades, and remember that some fans are designed to operate even after the ignition is turned off.
- E. Wear safety glasses when using compressed air for cleaning, and NEVER direct compressed air at a fellow worker, even in jest, because horseplay is strictly forbidden in an automotive shop.
- F. Wear safety glasses, safety goggles, or a face shield as a job may require, and never place your head directly over a battery or over any spring-loaded device that you're working on.
- G. Practice good housekeeping at all times, and this includes keeping tools and equipment clean and stored in proper places.

### IV. Fire safety

- A. Know the location of all fire extinguishers, the types of extinguishers they are, and the procedure for their proper operation. (Transparency #1)
- B. Know the location of fire exits, keep them clean, and keep fire doors unobstructed.
- C. Do not use gasoline or carbon tetrachloride as cleaning agents because both create fire hazards, and fumes from carbon tetrachloride are toxic.
- D. Use welding/cutting equipment away from areas where flammable liquids are stored, and only where there is proper ventilation.
- E. Store flammable liquids only in safety containers, and in designated areas.
- F. Never operate an engine when fuel is leaking from the carburetor, fuel pump, or fuel line.
- G. In case of a fire in a vehicle, turn the ignition off, disconnect the positive (+) battery cable, and then use a CO<sub>2</sub> or dry chemical fire extinguisher.
- H. When servicing a battery, always disconnect the negative cable first, but in a fire emergency, it is important to disconnect the positive cable in order to stop the power supply; if the problem is a short to ground, disconnecting the negative battery cable would not stop the problem.
- I. Smoke only in designated areas.

## INFORMATION SHEET

### V. Battery safety

- A. The first rule for battery safety is to wear safety glasses or goggles for any type of battery service, and never place your head directly over a battery you are working on.
- B. When removing a battery from a vehicle, always disconnect the ground (-) cable first, and reconnect the ground cable last when reinstalling a battery.
- C. Use a battery strap when removing, replacing, or transporting a battery.
- D. Loosen battery clamps with a box-end wrench to avoid sparking, and work the battery clamps off by hand or with a screw-type puller, but never pry battery clamps off.
- E. Charge batteries only in well ventilated areas that are free of any danger from sparks or open flames.
- F. When using jumper cables, connect the vehicle battery first, and make sure clamps are secure; when disconnecting jumper cables, disconnect the jumper battery first.

### VI. Steps in safe lifting

- A. Step 1 — Look at the load you plan to lift and size it up to make sure it is not too heavy or unwieldy for you to handle.

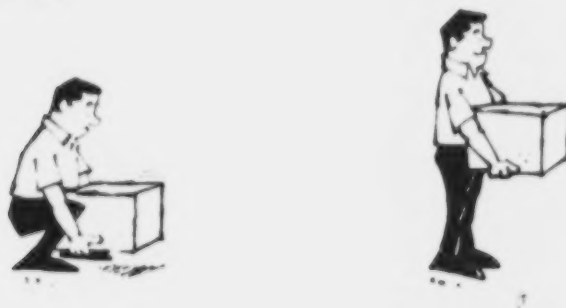
FIGURE 1



## INFORMATION SHEET

- B. Step 2 — Keep your back straight as you bend to pick up the load, get a firm grip on the object, and lift with your back and leg muscles as you keep the load close to your body.

FIGURE 2



- C. Step 3 — Complete the lift before you turn to make sure your path of travel is clear, move the load, and then set the load down by bending your knees and using back and leg muscles together.

FIGURE 3



### VII. Ways to recognize shock

- A. Skin is pale and bluish.
- B. Skin may be moist and clammy, even cold to the touch.
- C. Victim feels weak.
- D. Pulse is rapid and weak.
- E. Breathing rate is fast and irregular.
- F. Victim may be confused or incoherent.



## INFORMATION SHEET

### VIII. Steps in treating shock

- A. Notify supervisor or instructor IMMEDIATELY.
- B. DO NOT DELAY immediate first aid treatment; it can be life saving.
- C. Eliminate the causes of shock, control bleeding, or administer artificial respiration if victim is not breathing.
- D. Keep victim lying down with feet slightly elevated.

**(CAUTION: If victim has sustained a head, chest, or back injury, do not elevate the feet. Leave the victim lying flat, and when in doubt about the nature of the wound, leave the victim lying flat.)**

- E. Cover the victim to retain body heat, but do not make the victim sweat.
- F. Give no liquids or food to the victim.

### IX. First aid for eye injury

- A. Every eye injury should receive immediate first aid attention.
- B. Notify your supervisor or instructor immediately.
- C. For an apparent minor object in the eye, have the person wink several times. If the tears produced by winking do not remove the object, assume that the object is embedded and use the following procedure:
  - 1. Have the victim close his or her eyes.
  - 2. Place a piece of moist cotton over the closed lid.
  - 3. Place a bandage over the cotton.
  - 4. Get the victim to a doctor as soon as possible.
- D. When the eyeball has been obviously scratched or penetrated, apply a sterile dressing, bandage *loosely*, and get medical help immediately.
- E. Never permit the victim of an eye injury to rub his or her eye.
- F. When in doubt about an eye injury, seek the most immediate medical attention whether it's on the job or in the classroom.
- G. Even though damage may be confined to one eye, it is sometimes best to bandage both eyes with a sterile dressing so the victim will not have a tendency to move the damaged eye.

## INFORMATION SHEET

- H. For chemical or acid splashes, flush the eyes immediately at an eye-flushing station or use bottled, portable flushing solution, then seek immediate medical assistance.

### X. General guidelines for first aid emergencies

- A. Never hesitate to administer first aid when it is needed.
- B. Always have a reason for what you do.
- C. Reassure the injured person that everything possible is being done.
- D. Make accurate notes about the accident including name of victim, time, place, cause or nature of the accident, and any first aid that was administered.
- E. Do not notify the victim's family because this is the responsibility of the school, the jobsite supervisor, or the medical facility.
- F. Report all accidents and injuries to your instructor or jobsite supervisor, no matter how minor they may seem to be.
- G. File a complete accident report and submit a copy to the proper persons.

(NOTE: Follow emergency procedures that have been adopted by local school board.)

### XI. Personal physical and hygiene requirements

- A. Take a bath or shower daily

(NOTE: This should be a matter of personal pride, a matter of habit, but beyond that, it's a responsibility to your fellow workers and classmates.)

- B. Stay in good physical condition because this also promotes good psychological health.
- C. Do not drink alcoholic beverages or use drugs on the job, and don't show up for work with a hangover.

(CAUTION: Even at the hangover stage, alcohol impairs judgment and endangers co-workers, and drugs are both physically and psychologically damaging.)

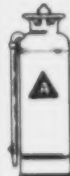
- D. Pay attention all the time because the majority of accidents happen to beginners in their first few months of work.

## INFORMATION SHEET

### XII. Service responsibilities

- A. Returning a clean vehicle to a customer is an important part of being a good service technician because it promotes good customer relations.
- B. Leaning over to work in an engine compartment requires using fender guards to avoid leaving grease or oil stains or scratches on fenders.
- C. Cover seats or any other areas that could be soiled when working in the passenger compartment.
- D. Handle brake fluid with care because one drop spilled on a painted surface can leave a blemish.
- E. Do not work with oily gloves on, and develop the habit of keeping your hands clean so that you will not leave unsightly smudges on knobs, handles, or other parts that have to be touched during service and repair.
- F. Remember that a service technician is part of a team that is out to promote a good company image by maintaining good customer relations.

# Fire Safety

| KIND OF FIRE                                                                                                                                                                                                                                                                            |                                                              | APPROVED TYPE OF EXTINGUISHER                                                      |                                                                                     |                                                                                   |                                                                                    |                                                                                     |                                                                                       |                                                                                       |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------|------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------|------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------|
| DECIDE THE CLASS OF FIRE YOU ARE FIGHTING. . .<br>↓                                                                                                                                                                                                                                     | . . . THEN CHECK THE COLUMNS TO THE RIGHT OF THAT CLASS<br>→ | MATCH UP PROPER EXTINGUISHER WITH CLASS OF FIRE SHOWN AT LEFT                      |                                                                                     |                                                                                   |                                                                                    |                                                                                     |                                                                                       |                                                                                       |
|                                                                                                                                                                                                                                                                                         |                                                              | FOAM<br>Solution of Aluminum Sulphate and Bicarbonate of Soda                      | CARBON DIOXIDE<br>Carbon Dioxide Gas Under Pressure                                 | SODA ACID<br>Bicarbonate of Soda Solution and Sulphuric Acid                      | PUMP TANK<br>Plain Water                                                           | GAS CART-RIDGE<br>Water Expelled by Carbon Dioxide Gas                              | MULTI-PURPOSE DRY CHEMICAL                                                            | ORDINARY DRY CHEMICAL                                                                 |
| <br><b>CLASS A FIRES</b><br>USE THESE EXTINGUISHERS<br><br>ORDINARY COMBUSTIBLES<br>• WOOD<br>• PAPER<br>• CLOTH ETC. | →                                                            |   | X                                                                                   |  |  |  |    | X                                                                                     |
| <br><b>CLASS B FIRES</b><br>USE THESE EXTINGUISHERS<br>FLAMMABLE LIQUIDS, GREASE<br>• GASOLINE<br>• PAINTS<br>• OILS, ETC.                                                                           | →                                                            |  |   | X                                                                                 | X                                                                                  | X                                                                                   |   |   |
| <br><b>CLASS C FIRES</b><br>USE THESE EXTINGUISHERS<br>ELECTRICAL EQUIPMENT<br>• MOTORS<br>• SWITCHES ETC.                                                                                           | →                                                            | X                                                                                  |  | X                                                                                 | X                                                                                  | X                                                                                   |  |  |

## SAFETY AND ACCIDENT PREVENTION UNIT II

### ASSIGNMENT SHEET #1 — SOLVE SAFETY AND ACCIDENT PREVENTION PROBLEMS

- A. A co-worker is idling an engine on a vehicle, but has neglected to hook up a safety exhaust hose. When the lack of proper exhausting is pointed out, the co-worker says that since the engine is only idling, there will be no danger from exhaust fumes.

1. Is there a problem? \_\_\_\_\_
2. If there is a problem, how can it be solved? \_\_\_\_\_  
\_\_\_\_\_

- B. A co-worker is cleaning a dirty part with compressed air, and when you point out that he ought to be wearing safety glasses, he jokingly aims the compressed air at you.

1. Is there a problem? \_\_\_\_\_
2. If there is a problem, how can it be solved? \_\_\_\_\_  
\_\_\_\_\_

- C. You overhear two co-workers talking about whether or not the negative cable should be disconnected first when servicing a battery. Co-worker one says the negative cable should always be removed first and replaced last, but co-worker two insists that the positive cable should be removed first in order to cut the power supply to a circuit and help stop an automotive fire.

1. Is there a problem, or is it a matter of confusion? \_\_\_\_\_  
\_\_\_\_\_
2. Is co-worker one right and co-worker two wrong, or are both right, but simply not stating their positions clearly? Justify your answer. \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

## ASSIGNMENT SHEET #1

- D. Two co-workers are discussing potential danger areas around an automotive shop, and co-worker one insists that skinned knuckles and abrasions cause more lost work time than anything else. Co-worker two insists that eye injuries cause more lost work time than anything else?

1. Which co-worker is right? \_\_\_\_\_

2. How would you justify your answer? \_\_\_\_\_

\_\_\_\_\_

- E. A co-worker walks into the battery charging area while smoking a cigarette.

1. Is there a problem? \_\_\_\_\_

2. What safety rules are being broken? \_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

## SAFETY AND ACCIDENT PREVENTION UNIT II

### ASSIGNMENT SHEET #2 — COMPLETE A STUDENT SAFETY PLEDGE

#### STUDENT SAFETY PLEDGE FOR VOCATIONAL AUTOMOTIVE ELECTRONICS

\_\_\_\_\_, who is enrolled in vocational automotive studies at \_\_\_\_\_, will, as a part of the training program, operate machines and equipment. This activity requires the written permission of parent(s) or guardian.

1. I PROMISE TO ABIDE BY ALL SAFETY RULES FOR THE SHOP AS FOLLOWS:

- a. To use hand tools and power tools only after proper instruction and only with the instructor's permission
- b. To use all tools and equipment only for their intended purposes, and to wear safety glasses at all times in the shop area
- c. To exhibit a concern for tools and equipment by returning them to proper storage areas after use
- d. To contribute to good housekeeping requirements and to keep the shop area clean and safe
- e. To abide by all fire regulations and to respect no smoking signs or areas
- f. To avoid horseplay at all times
- g. To follow all rules and regulations of the school

2. I WILL REPORT ALL ACCIDENTS TO THE INSTRUCTOR IMMEDIATELY

DATE \_\_\_\_\_ STUDENT'S SIGNATURE \_\_\_\_\_

As parent(s) or guardian of \_\_\_\_\_, I hereby give consent for my son/daughter to operate all machines and equipment necessary for carrying out the requirements of the automotive course in which he/she is enrolled (parent or guardian signature not required for students of legal age).

DATE \_\_\_\_\_

PARENT(S) OR GUARDIAN SIGNATURE \_\_\_\_\_

(NOTE: Parents are cordially invited to visit the school and inspect the automotive electronics program at any convenient time.)

## **SAFETY AND ACCIDENT PREVENTION UNIT II**

### **ASSIGNMENT SHEET #3 — COMPLETE A SHOP SAFETY DRAWING**

Directions: Make a careful, neat drawing of the shop area. Include the location of fire extinguishers, first aid kit, eye flush station, and all emergency exits. Also list the telephone numbers to call in the event of fire or medical emergencies.



## SAFETY AND ACCIDENT PREVENTION UNIT II

### ANSWERS TO ASSIGNMENT SHEETS

#### Assignment Sheet #1

- A.
  - 1. Yes.
  - 2. Hook up a proper exhaust hose any time an engine is being run inside at any speed.
- B.
  - 1. Yes.
  - 2. Wear safety glasses when using compressed air, and never direct compressed air at someone else because horseplay is strictly forbidden in an automotive shop.
- C.
  - 1. It is a matter of confusion.
  - 2. Both co-workers are right. In normal battery service, the negative cable should always be disconnected first, but with an automotive fire, the positive cable should be disconnected first to cut off power to circuits.
- D.
  - 1. Neither is right.
  - 2. Workers compensation records indicate that back injuries and related problems are the number one cause of lost work time.
- E.
  - 1. Yes.
  - 2. Smoke only in designated areas, and the battery charging area should be free of any risk from spark or flame.

**Assignment Sheet #2** — Evaluated to the satisfaction of the instructor

**Assignment Sheet #3** — Evaluated to the satisfaction of the instructor

## SAFETY AND ACCIDENT PREVENTION UNIT II

### TEST

NAME \_\_\_\_\_

SCORE \_\_\_\_\_

1. Match terms related to safety and accident prevention with their correct definitions.

- |                                                                                                                                      |                 |
|--------------------------------------------------------------------------------------------------------------------------------------|-----------------|
| _____a. State or condition of being safe; freedom from danger, risk, or injury                                                       | 1. Combustibles |
| _____b. Any suddenly occurring, unintentional event which causes personal injury or property damage                                  | 2. Accident     |
| _____c. Immediate, temporary care given the victim of an accident or sudden illness until the service of a physician can be obtained | 3. Hygiene      |
| _____d. Materials or liquids that catch fire easily                                                                                  | 4. Safety       |
| _____e. The science of good health and its maintenance, including sanitary practice and cleanliness                                  | 5. First aid    |

2. Match automotive shop dangers with their causes.

- |                                                                                                                                                                                                      |                           |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------|
| _____a. Caused by running engines in a shop without properly removing exhaust gases                                                                                                                  | 1. Back injury            |
| _____b. Caused by charging batteries in improperly ventilated areas, use of improper cleaning agents, and careless use of drop lights and welding/cutting equipment                                  | 2. Cuts and bruises       |
| _____c. Almost always caused by improper lifting, and workers compensation records in almost every state indicate that back injuries and related problems are the number one cause of lost work time | 3. Exhaust gas inhalation |
| _____d. Almost always caused by failure to wear safety glasses or a face shield                                                                                                                      | 4. Bodily injury          |
| _____e. Caused by improperly using tools, failure to wear gloves and other protective clothing, and careless housekeeping that causes trips and falls                                                | 5. Explosions and fire    |
|                                                                                                                                                                                                      | 6. Eye injury             |

## TEST

- \_\_\_\_\_a. Caused by improper or careless use of jacks and lifts, and wearing improper clothing around moving or rotating equipment
3. Select true statements concerning general shop safety by placing an "X" beside each statement that is true.
- \_\_\_\_\_a. Operate power lifts according to manufacturers' directions, and make sure the descent area is clear before lowering a power lift.
- \_\_\_\_\_b. Use jack stands to secure a vehicle when you have to work under it, and remember that a jack handle sticking out into a walkway is a tripping hazard.
- \_\_\_\_\_c. Remove ties, rings, and jewelry when working in the shop, and confine long hair, especially when working around rotating parts.
- \_\_\_\_\_d. Keep hands free of fan blades, and remember that some fans are designed to operate even after the ignition is turned off.
- \_\_\_\_\_e. Wear safety glasses when using compressed air for cleaning, and NEVER direct compressed air at a fellow worker, even in jest, because horseplay is strictly forbidden in an automotive shop.
- \_\_\_\_\_f. Wear safety glasses, safety goggles, or a face shield as a job may require, and never place your head directly over a battery or over any spring-loaded device that you're working on.
- \_\_\_\_\_g. Practice good housekeeping at all times, and this includes keeping tools and equipment clean and stored in proper places.
4. Solve problems concerning fire safety by answering the following questions.
- a. Using carbon tetrachloride as a cleaning agent creates a fire hazard, but what other danger is associated with carbon tetrachloride?
- Answer: \_\_\_\_\_
- b. In the case of a vehicle fire, which battery cable should be disconnected first?
- Answer: \_\_\_\_\_
5. Complete statements concerning battery safety by circling the word(s) that best complete(s) each statement.
- a. The first rule for battery safety is to wear (**safety glasses or goggles, heavy rubber gloves**) for any type of battery service, and never place your head directly over a battery you are working on. -

## TEST

- b. When removing a battery from a vehicle, always disconnect the **(ground, positive)** cable first and reconnect the **(ground, positive)** cable last when reinstalling a battery.
  - c. Use a **(cart, battery strap)** when removing, replacing, or transporting a battery.
  - d. Loosen battery clamps with a **(box-end wrench, screwdriver)** to avoid sparking, and work the battery clamps off by hand or with a screw-type puller, but never pry battery clamps off.
  - e. Charge batteries only in well ventilated areas that are free of any danger from sparks or open **(flames, containers)**.
  - f. When using jumper cables, connect the **(vehicle, jumper)** battery first, and make sure clamps are secure; when disconnecting jumper cables, disconnect the **(jumper, vehicle)** battery first.
6. Arrange in order the steps in safe lifting by placing the correct sequence number in the appropriate blank.
- \_\_\_\_\_a. Complete the lift before you turn to make sure your path or travel is clear, move the load, and then set the load down by bending your knees and using back and leg muscles together.
  - \_\_\_\_\_b. Look at the load you plan to lift and size it up to make sure it is not too heavy or unwieldy for you to handle.
  - \_\_\_\_\_c. Keep your back straight as you bend to pick up the load, get a firm grip on the object, and lift with your back and leg muscles as you keep the load close to your body.
7. Select true statements concerning ways to recognize shock by placing an "X" beside each statement that is true.
- \_\_\_\_\_a. Skin is pale and bluish.
  - \_\_\_\_\_b. Skin may be moist and clammy, even cold to the touch.
  - \_\_\_\_\_c. Victim feels weak.
  - \_\_\_\_\_d. Pulse is slow and strong.
  - \_\_\_\_\_e. Breathing rate is slow.
  - \_\_\_\_\_f. Victim may be confused or incoherent.

## TEST

8. Arrange in order the steps in treating shock by placing the correct sequence number in the appropriate blank.

- \_\_\_\_ a. Cover the victim to retain body heat, but do not make the victim sweat.
- \_\_\_\_ b. Give no liquids or food to the victim.
- \_\_\_\_ c. Notify supervisor or instructor IMMEDIATELY.
- \_\_\_\_ d. DO NOT DELAY immediate first aid treatment; it can be life saving.
- \_\_\_\_ e. Eliminate the causes of shock, control bleeding, or administer artificial respiration if the victim is not breathing.
- \_\_\_\_ f. Keep victim lying down with feet slightly elevated.

9. Complete statements concerning first aid for eye injury by circling the word(s) that best complete(s) each statement.

- a. **(Every eye injury, Almost all eye injuries)** should receive immediate first aid attention.
- b. Notify your supervisor or instructor **(Immediately, at the first opportunity)**.
- c. For an apparent minor object in the eye, have the person wink several times. If the tears produced by winking do not remove the object, assume that the object is embedded and use the following procedure:
  - 1) Have the victim **(close his or her eyes, lie down)**.
  - 2) Place a piece of **(dry, moist)** cotton over the closed lid.
  - 3) Place a **(bandage, band-aid)** over the cotton.
  - 4) Get the victim to **(a doctor, a rest area)** as soon as possible.
- d. When the eyeball has been obviously scratched or penetrated, apply a sterile dressing, bandage **(loosely, firmly)**, and get medical help immediately.
- e. Never permit the victim of an eye injury to **(rub, touch)** his or her eye.
- f. When in doubt about an eye injury, **(get any sort of help you can, seek the most immediate medical attention)** whether it's on the job or in the classroom.
- g. Even though damage may be confined to one eye, it is sometimes best to bandage both eyes with a sterile dressing so the victim will not have a tendency **(to move the damaged eye, to roam about)**.

## TEST

- h. For chemical or acid splashes, flush the eyes (**immediately, within 5 minutes**) at an eye-flushing station or use bottled, portable flushing solution, then seek immediate medical assistance.
10. Select true statements concerning guidelines for first aid emergencies by placing an "X" beside each statement that is true.
- \_\_\_\_a. Never hesitate to administer first aid when it is needed.
  - \_\_\_\_b. Always do something even if you're not sure.
  - \_\_\_\_c. Reassure the injured person that everything possible is being done.
  - \_\_\_\_d. Make accurate notes about the accident including name of victim, time, place, cause or nature of the accident, and any first aid that was administered.
  - \_\_\_\_e. Do notify the victim's family because this is your responsibility.
  - \_\_\_\_f. Report all accidents and injuries to your instructor or jobsite supervisor, no matter how minor they may seem to be.
  - \_\_\_\_g. File a complete accident report and submit a copy to the proper persons.
11. Solve problems concerning personal physical and hygiene requirements by answering the following questions.
- a. Staying in good physical condition promotes what other health area?  
Answer: \_\_\_\_\_
  - b. When do a majority of accidents happen to beginners?  
Answer: \_\_\_\_\_
12. Complete statements concerning service responsibilities by circling the word(s) that best complete(s) each statement.
- a. Returning a (**clean, good running**) vehicle to a customer is an important part of being a good service technician because it promotes good customer relations.
  - b. Leaning over to work in an engine compartment requires using (**drop cloths, fender guards**) to avoid leaving grease or oil stains or scratches on fenders.
  - c. Cover (**seats, floor mats**) or any other areas that could be soiled when working in the passenger compartment.

## TEST

- d. Handle (**brake fluid, transmission fluid**) with care because one drop spilled on a painted surface can leave a blemish.
- e. Do not work with oily gloves on, and develop the habit of keeping your hands clean so that you will not leave (**unsightly smudges, fingerprints**) on knobs, handles, or other parts that have to be touched during service and repair.
- f. Remember that a service technician is part of a team that is out to promote (**a good company image, the team concept**) by maintaining good customer relations.

(NOTE: If the following activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

- 13. Solve safety and accident prevention problems. (Assignment Sheet #1)
- 14. Complete a student safety pledge. (Assignment Sheet #2)
- 15. Complete a shop safety drawing. (Assignment Sheet #3)



## SAFETY AND ACCIDENT PREVENTION UNIT II

### ANSWERS TO TEST

1.   a.    4  
     b.    2  
     c.    5  
     d.    1  
     e.    3
  
2.   a.    3  
     b.    5  
     c.    1  
     d.    6  
     e.    2  
     f.    4
  
3.   a, b, c, d, e, f, g
  
4.   a.    Carbon tetrachloride is toxic  
     b.    The positive cable
  
5.   a.    Safety glasses or goggles  
     b.    Ground, ground  
     c.    Battery strap  
     d.    Box-end wrench  
     e.    Flames  
     f.    Vehicle, jumper
  
6.   a.    3  
     b.    1  
     c.    2
  
7.   a, b, c, f
  
8.   a.    5  
     b.    6  
     c.    1  
     d.    2  
     e.    3  
     f.    4



## ANSWERS TO TEST

9. a. Every eye injury  
b. Immediately  
c. 1) Close his or her eyes  
2) Moist  
3) Bandage  
4) A doctor  
d. Loosely  
e. Rub  
f. Seek the most immediate medical attention  
g. To move the damaged eye  
h. Immediately
10. a, c, d, f, g
11. a. Good psychological health  
b. In the first few months of work
12. a. Clean  
b. Fender guards  
c. Seats  
d. Brake fluid  
e. Unsightly smudges  
f. A good company image
13. Evaluated to the satisfaction of the instructor
14. Evaluated to the satisfaction of the instructor
15. Evaluated to the satisfaction of the instructor



## AUTOMOTIVE DC ELECTRONICS UNIT III

### UNIT OBJECTIVE

After completion of this unit, the student should be able to discuss the nature of matter and the basic fundamentals of direct current electricity. The student should also be able to recognize series and parallel circuits as well as batteries, alternators, conductors, insulators, connectors, breakers, fuses, capacitors, switches, and relays. The student should also be able to use Ohm's law to compute unknown voltage, resistance, and amperage, and check troubles in series and parallel circuits. These competencies will be evidenced by correctly completing the procedures outlined in the assignment and job sheets and by scoring 85 percent on the unit test.

### SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms related to automotive DC electronics with their correct definitions.
2. Select true statements concerning the nature of matter.
3. Solve a problem concerning static electricity.
4. Select true statements concerning dynamic electricity.
5. Complete statements concerning batteries.
6. Complete statements concerning alternators.
7. Select true statements concerning ohm's law.
8. Solve problems concerning Kirchoff's law for voltage and current.
9. Solve problems concerning theories of current flow.
10. Identify a series circuit.
11. Identify a parallel circuit.
12. Identify a series-parallel circuit.
13. Complete statements concerning voltage measurements.
14. Complete statements concerning current measurements.
15. Complete statements concerning resistance measurements.

**OBJECTIVE SHEET**

16. Select true statements concerning multimeters.
17. Select true statements concerning linear DC.
18. Select true statements concerning pulsating DC.
19. Complete statements concerning conductors.
20. Solve problems concerning insulators.
21. Solve problems concerning connectors.
22. Complete statements concerning fuses and fusible links.
23. Complete statements concerning circuit breakers.
24. Select true statements concerning inductors.
25. Select true statements concerning capacitors.
26. Complete true statements concerning switches.
27. Solve problems concerning electromechanical relays.
28. Complete statements concerning schematic diagrams.
29. Complete statements concerning scientific notation.
30. Select true statements concerning troubleshooting an open circuit.
31. Select true statements concerning troubleshooting a short to ground.
32. Select true statements concerning troubleshooting shorts into another circuit.
33. Select true statements concerning troubleshooting high-resistance problems.
34. Calculate voltage using Ohm's law. (Assignment Sheet #1)
35. Calculate current flow in amperes using Ohm's law. (Assignment Sheet #2)
36. Calculate resistance using Ohm's law. (Assignment Sheet #3)
37. Demonstrate the ability to:
  - a. Measure voltage drops in a series circuit. (Job Sheet #1)
  - b. Analyze current values in a series circuit. (Job Sheet #2)
  - c. Measure voltage, current, and resistance in a parallel circuit. (Job Sheet #3)
  - d. Troubleshoot series-parallel circuits. (Job Sheet #4)

## AUTOMOTIVE DC ELECTRONICS UNIT III

### SUGGESTED ACTIVITIES

- A. Provide students with objective sheet.
- B. Provide students with information and assignment sheets.
- C. Make transparencies.
- D. Discuss unit and specific objectives.
- E. Discuss information and assignment sheets.
- F. Have available automotive components to demonstrate how switches, capacitors, relays, and other electronic items are used in automobiles.
- G. Demonstrate the measurement of amps, volts, and ohms with the different types of instruments they can be measured with.
- H. Demonstrate how to zero an ohmmeter and adjust it to get a proper reading.
- I. Impress upon students the need for safe practices when using test instruments.
- J. Read the job sheets carefully and prepare test circuits as needed so the students can get some hands-on practice with real circuits.
- K. Give test.

### REFERENCES USED IN DEVELOPING THIS UNIT

- A. *EEC III EEC IV 5-DAY TECHNICIAN CERTIFICATION*. Dearborn, MI 48121: Ford Parts and Service Division, Training and Publications Department, 1985.
- B. *Electricity and Electronics, Fundamentals*. Highland Park, MI 48203: Service Training, Chrysler Corporation, 1984.
- C. *Specialized Electronics Training*. Warren, MI 48090: Product Service Training, General Motors Corporation, 1984.
- D. Willison, Neal and James Shelton. *Basic Electronics II*. Stillwater, OK: Mid-America Vocational Curriculum Consortium, 1981.

## **AUTOMOTIVE DC ELECTRONICS UNIT III**

### **INFORMATION SHEET**

#### **I. Terms and definitions**

- A. Battery — Portable, chemical source of electricity
- B. Capacitor — Electronic component that stores energy in an electrostatic field
- C. Conductors — Materials that pass electricity easily
- D. Current — The rate of flow of electrical charge, measured in amperes; the symbol for current is I
- E. Electrons — Atomic particles that have a negative charge
- F. Elements — Basic building blocks of matter
- G. Inductors — Electronic component that stores energy in a magnetic field
- H. Insulators — Materials that do not pass electricity easily
- I. Ion — An atom that has gained or lost an electron
- J. Neutron — Atomic particle that has no electric charge
- K. Proton — Atomic particle with a positive electric charge
- L. Resistor — Electronic component that resists the flow of electricity, converts electrical energy to heat, unit is the ohm, symbol is  $\Omega$
- M. Voltage — Electrical pressure that can force current to flow through resistance, unit is volt, symbols used are V and E

#### **II. Nature of matter**

- A. All matter is made up of basic building blocks called elements.
- B. There are over 100 naturally occurring elements such as oxygen, hydrogen, carbon, and iron.
- C. Elements can combine to produce common forms of matter.  
  
Example: Oxygen can combine with hydrogen to produce water or iron can combine with carbon to form steel
- D. Each element has its own unique atomic structure.

## INFORMATION SHEET

- E. An atom is made up of two parts, a dense nucleus and electrons that orbit the nucleus.
- F. The nucleus of an atom has two kinds of atomic particles, neutrons and protons.
- G. Electrons have a *negative* electrical charge.
- H. Protons have a *positive* electrical charge.
- I. Neutrons have *no* electrical charge.
- J. The negative electrical charge of an electron is the same size as the positive charge of a proton.
- K. In a normal atom there are as many orbiting electrons as protons in the nucleus. (Transparency 1)
- L. Under certain conditions, an atom may gain an extra electron or lose an orbiting electron. (Transparency 2)
- M. If an atom gains or loses an orbiting electron, the atom is no longer electrically neutral — the atom has become an *ion*.
- N. If an atom loses an orbiting electron, the atom has a net positive charge and is called a positive ion.
- O. An electron lost from an atom is called a free electron.
- P. When an atom loses an electron the empty space left in the atom is called a hole.
- Q. If an atom gains an extra orbiting electron, the atom has a net negative charge and is called a negative ion.
- R. The movement of electrons is considered electricity.

### III. Static electricity

- A. Free electrons can gather on the surface of a material to create a negative static electrical charge.
- B. A nonmoving electrical charge is called static electricity.

## INFORMATION SHEET

- C. The easiest way to create static electricity is to create friction between two different substances.

Example: Sliding across a car seat will often produce static electricity.

- D. On a dry day, a comb that has been used to comb hair will be electrically charged with static electricity and can be used to attract small bits of paper.

- E. Static electricity will remain static until a conducting path allows a discharge.

Example: Many have walked across a carpeted room on a dry winter day and experienced an electrical discharge as they touched the doorknob.

- F. An awareness of static electricity is necessary because electrostatic discharge can accidentally damage or destroy sensitive electronic components, and static discharge has to be controlled by static grounding.

Example: Wrist straps grounded to chassis are commonly used for static grounding.

### IV. Dynamic electricity

- A. Dynamic or moving electrons are called an *electrical current*.
- B. Electrons can quickly form an electric current if placed near positive ions, the positively charged ions attract the electrons which rush to fill the holes left by missing electrons.
- C. Electrons will be repelled by negative ions because *like charges repel* and *unlike charges attract*. (Transparency 3)
- D. Electric currents flow easily through metal wires called conductors.
- E. The best metals for electrical conductors are gold, silver, copper, and aluminum, and copper is the most commonly used electrical conductor.
- F. Electrical pressure supplied by a battery or other source can make current flow through a conducting path known as a circuit.
- G. The electrical pressure that causes an electrical current to flow through a closed electrical path is called voltage.
- H. The unit of measure of electrical pressure is the volt.
- I. The measure of how much current flows through a conductor is the ampere.



## INFORMATION SHEET

- J. When an electrical resistance such as a light bulb is placed in the path of an electrical current, the measure of electrical resistance is the ohm.
- K. When an electrical current passes through an electrical resistance or other electrical load, work is done, and electrical energy is transformed into heat, light, or forms of mechanical work.
- L. The measure of work performed by electrical energy is the watt.

### V. Batteries

- A. One of the main sources of portable electricity is the battery.
- B. Batteries convert chemical energy into electricity. (Transparency 4)
- C. Batteries are composed of a chemical solution called an electrolyte and two different kinds of metals called the plates.
- D. The positive ions in an electrolyte collect on one of the battery plates and the negative ions in an electrolyte collect on the other battery plate.
- E. A battery is made up of battery cells connected in a series.
- F. The most common battery used in automobiles is called a lead-acid battery.
- G. Automobile batteries are made up of six lead-acid cells connected in series to give a battery voltage of 12 volts.
- H. Each of the lead-acid cells making up the battery produces approximately 2 volts.
- I. Lead-acid batteries used in automobiles can supply electrical energy to do work such as turn a starter motor or light head lamps.
- J. As a battery supplies energy or power, the battery discharges the chemical action that produces electricity decreases, and an internal resistance develops that limits maximum current flow.
- K. An automobile battery can also be recharged with an alternator.

### VI. Alternators (Transparency 5)

- A. When an electric current flows through a conductor, it establishes a magnetic field around the conductor.
- B. Since a moving electric charge creates a magnetic field, the key words are movement, electric charge, magnetic field, and if any two of the above are present, the third will occur.



## INFORMATION SHEET

- C. *Moving a conductor across a magnetic field will create an electrical current in the conductor that will flow through the complete electrical circuit.*
- D. The concept of inducing electricity is used to build electric generators and automobile alternators which are used to charge automotive batteries.
- E. The alternator voltage is slightly greater than the battery voltage and forces a reversal of the chemical action within the battery, and reversal action recharges the battery.

### VII. Ohm's law (Transparency 6)

- A. Ohm's law expresses the relationship of voltage, current, and resistance in an electrical circuit.
- B. Ohm's law states: The current flowing in an electrical circuit is directly proportional to the voltage, and inversely proportional to the circuit resistance.
- C. Ohm's law uses symbols to represent the three electrical quantities:
  - 1. E is the symbol for voltage (pressure), and is measured in volts.
  - 2. I is the symbol for current (rate of flow), and is measured in amperes.
  - 3. R is the symbol for resistance (load), and is measured in ohms.
- D. When at least two electrical quantities are known, Ohm's law can be used to find the other unknown quantity, as expressed in mathematical formulas:
  - 1.  $E = I \times R$  (amperage times resistance)
  - 2.  $I = E / R$  (voltage divided by resistance)
  - 3.  $R = E / I$  (voltage divided by amperage)

### VIII. Kirchhoff's law for voltage and current

- A. Kirchhoff's voltage law — The sum of the voltage drops in a closed loop circuit (series circuit) is equal to the applied voltage.
- B. Kirchhoff's current law — The algebraic sum of currents into any point in a circuit is equal to the algebraic sum of currents out of that point.

### IX. Theories of current flow

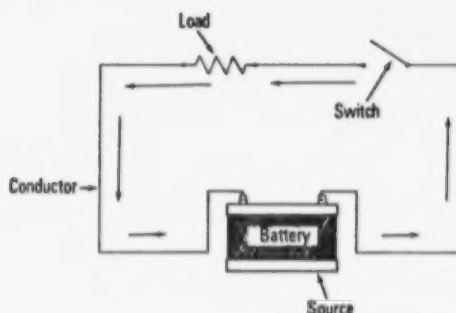
- A. The electron theory of current flow states that current flows from the negative battery terminal (-) through a circuit, and back to the positive battery terminal (+).

## INFORMATION SHEET

- B. The conventional theory of current flow states that current flows from the positive battery terminal (+) through a circuit, and back to the negative battery terminal (-).
- C. The conventional theory of current flow is the accepted theory used in automotive applications, and in solid-state electronics applications.

FIGURE 1

### Basic Circuit



- D. Confusing the two theories can lead to misreading schematics, and errors in troubleshooting, so always know which theory is being used, and remember that the conventional theory is used in automotive applications.
- X. **Series circuits** (Transparency 7)

- A. Current flow in a series circuit follows a single continuous path through the load devices.
- B. An open in any part of a series circuit stops current flow in a series circuit.
- C. Each resistance or load in a series circuit has its own voltage drop which equals the resistance of the load times the current flow.

Example:  $V_1 = I \times R_1$   
 $V_2 = I \times R_2$

- D. The sum of all the voltage drops in a series circuit will equal the battery voltage.
- E. Total resistance in a series circuit equals the sum of all resistances in the circuit.

Example:  $R_T \text{ (total resistance)} = R_1 + R_2 + R_3$

## INFORMATION SHEET

### XI. Parallel circuits (Transparency 7)

- A. Current flow in a parallel circuit can follow several different paths or branches through the load devices.
- B. If there is an open in one branch, current will still flow through the other branches in a parallel circuit.
- C. The total current flow in a parallel circuit is equal to the sum of the current flow in each of the branches.
- D. Since the same amount of voltage is applied to each load in a parallel circuit, the total voltage drop across each of the loads is equal to the battery voltage.
- E. Total resistance in a parallel circuit is less than the lowest resistance of any of the branch loads.
- F. There are two formulas for calculating total resistance in a parallel circuit:

$$\frac{R_1 \times R_2 \times R_3}{R_1 + R_2 + R_3} \quad \text{or} \quad \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}}$$

### XII. Series-parallel circuits (Transparency 7)

- A. Current flow in a series-parallel circuit can follow a single continuous path at one point, and follow several different paths at other points.

(NOTE: As the name implies, a series-parallel circuit has characteristics of both a series, and a parallel circuit.)

- B. If there is an open in the series part of a series-parallel circuit, current flow will stop, but if there is an open in a branch, current flow will stop in that branch, but not in the circuit.
- C. In a series-parallel circuit, the resistance of the load devices in the series part of the circuit drops the voltage to the level of the load devices in the parallel parts of the circuit.
- D. To calculate total resistance in a series-parallel circuit:
  - 1. Total the resistance of all the parallel branches.
  - 2. Total the series resistance.
  - 3. Add the two together to obtain total resistance.

(NOTE: Common automotive applications of series-parallel circuits include the use of a switch series to light instrument panels where lamps are wired in parallel.)

## INFORMATION SHEET

### XIII. Voltage measurements (Transparency 8)

- A. Voltage measurements are made with a voltmeter.
- B. Voltages are measured *across* resistors and sources such as batteries and power supplies.
- C. Voltmeters have very *high* resistance in order not to disturb the circuit under test.
- D. Since the voltmeter is across a resistor or source, it is in parallel with the resistor or source.
- E. There are two common types of voltmeters, analog and digital.
- F. Analog voltmeters indicate a voltage reading with a pointer on a scale.
- G. Digital voltmeters indicate the voltage reading as a digital display and have to be used in some applications.

### XIV. Current measurements (Transparency 9)

- A. Current measurements are made with an ammeter.
- B. Current measurements are made by placing the ammeter in series with the circuit being measured:
  - 1. The circuit must be opened and the meter placed into the circuit.
  - 2. The circuit must flow through the ammeter.
- C. Ammeters must have very *low* resistance; the presence of the ammeter should change the circuit under test as little as possible.
- D. There are two kinds of ammeters, analog and digital.

### XV. Resistance measurements (Transparency 10)

- A. Resistance measurements are made with an ohmmeter.
- B. Resistance must *not* be measured with an ohmmeter while power is applied to the circuit.

(NOTE: The resistor or circuit component is usually removed from the circuit before its resistance is measured.)
- C. An ohmmeter contains its own voltage source, usually a low voltage battery.
- D. Ohmmeters are available as both analog and digital instruments.

## INFORMATION SHEET

### XVI. Multimeters (Transparency 11)

- A. Since common circuit measurements are voltage, current, and resistance, these functions have been incorporated into a single instrument called a multimeter.
- B. To use a multimeter, the function switch is first turned to the quantity to be measured, voltage, current, or ohms.
- C. Once the function has been set, select the range of the quantity to be measured.

(NOTE: Many modern digital instruments have auto-ranging. If auto-ranging is not available and the range of the quantity to be measured cannot be estimated, set the instrument on the highest range, connect the instrument to the circuit, and then down range to get the reading.)

- D. Multimeters are available as analog or digital instruments.
- E. Digital multimeters are easier to read, and in high impedance applications, they do a better job than analog meters.
- F. Remember that a multimeter becomes a voltmeter, an ammeter, or an ohmmeter depending on the function switch setting.
- G. The multimeter is the most widely used basic circuit analysis and testing tool in electronics.

### XVII. Linear DC (Transparency 12)

- A. Linear DC is a constant or near constant value.
- B. Linear DC may be either positive or negative with respect to a reference point such as the automobile chassis.

### XVIII. Pulsating DC (Transparency 12)

- A. Pulsating DC changes value with time, but never crosses the zero reference.
- B. Pulsating DC may be either positive or negative with respect to a reference point such as the automobile chassis.
- C. A sophisticated instrument called an oscilloscope is used to measure pulsating DC.

## INFORMATION SHEET

### XIX. Conductors

- A. Conductors are the wires or metals that easily conduct electrical currents in circuits.
- B. The most common electrical conductor is copper wire.
- C. All conductors have some resistance based on length, diameter, and temperature:
  - 1. The longer the wire, the higher the resistance.
  - 2. The smaller in diameter the wire, the higher the resistance.
  - 3. The hotter the wire, the higher the resistance.
- D. The important characteristics of copper conductors are summarized in a wire gauge table. (Transparency 13)

### XX. Insulators

- A. Insulators are poor conductors of electrical current.
- B. Common insulating materials are rubber, plastics, glass, and ceramics.
- C. Insulating materials are used to cover conductors to offer protection for both the circuit and technicians working on circuits.
- D. If an insulator fails, a short circuit may occur, and excessive current flow will damage circuit components and perhaps start a fire.

### XXI. Connectors

- A. Many electrical connectors are connected to the conductors of a circuit or cable by solder.
- B. Solder is a mixture of lead and tin, a metal with a low melting temperature (compared to copper).
- C. Solder is used to make electrical connections between conductors; it is *not* used to create a strong mechanical connection.
- D. To properly solder a connection:
  - 1. Clean the connection or joint with a resin paste or flux.
  - 2. Heat the joint with a soldering iron.
  - 3. Apply the solder so that it melts and forms a bright, smooth appearance at the joint.
  - 4. Tape the connection to insulate it from corrosion.

## INFORMATION SHEET

- E. Common errors in soldering are:
1. Failure to properly clean the joint.
  2. Not heating the joint sufficiently, forming a cold solder joint that looks dull and rough.
  3. Using too much solder.
  4. Using improper flux
- F. In automotive circuits, connections are often made with crimp connectors.
- G. Crimp connectors are special connectors that have a sleeve that the conductor is slipped into; the sleeve is crushed using a special tool to form a mechanically strong solderless connection.
- H. If the crimp connection is subjected to long periods of vibration, the joint may fail by breaking the conductor at the crimp.
- I. A newer and far superior technique is to use solder to form the electrical connection and to make the connection corrosion resistant by covering it with heat shrink.
- J. While the conductor is soldered to the connector, the crimp is made on the conductor's insulation.

### XXII. Fuses and fusible links

- A. A low cost and effective method of protecting circuits from excessive current flow is to fuse the circuit.
- B. A fuse is a metal link selected and shaped to allow continuous current flow up to some predetermined amperage.
- C. When predetermined amperage is exceeded, the metal link melts, and the fuse blows.
- D. When a fuse blows, it is calling attention to a circuit problem that should be corrected.
- E. *Never* replace a fuse with one that has a higher amperage rating because circuit protection will be lost.
- F. Replacing a fuse with one with a higher rating may lead to expensive destruction of circuit components and/or electrical fires.



## INFORMATION SHEET

- G. Fusible links are used in power circuits, and like all other fuses, should be replaced with a fusible link of the same resistance. (Figure 1)

FIGURE 1



### XXIII. Circuit breakers

- A. Circuit breakers are circuit protectors that can be usually be reset, and don't have to be replaced like fuses do.
- B. Circuit breakers are usually of the thermal type; when they get too hot from excessive current flowing through them, the circuit they are protecting is opened.
- C. Thermal circuit breakers are composed of a small resistor used as a heating element and a bi-metal switch.

(NOTE: As the resistor overheats from excessive current passing through it, a bi-metal switch is forced to open. This type circuit breaker may be reset after it is allowed to cool.)

- D. A bi-metal switch is composed of two different metals that expand at different rates as they are heated.
- E. If a circuit breaker continues to trip, it's a sure sign that the circuit needs to be tested.

### XXIV. Inductors

- A. A current flowing through a conductor produces a magnetic field around the conductor.
- B. The effects of this magnetic field may be strengthened by forming the conductor into a coil; the result is called an inductor.



## INFORMATION SHEET

- C. The inductor has many uses in electrical and electronic circuits.
- D. An inductor may be wound to form an ignition coil to produce high voltage from a low voltage source:
  1. When the circuit closes, current flows through only part of the coil and a slowly expanding magnetic field is created around the entire coil or inductor.
  2. When the circuit opens, the magnetic field quickly collapses inducing a very high voltage in the total coil, and this high voltage is used to fire spark plugs.
  3. The magnetic field is strengthened by inserting a soft iron core into the center of the coil.

### XXV. Capacitors (Transparency 14)

- A. Capacitors are two plates of conducting material separated by an insulating material called a dielectric.
- B. A capacitor may be charged — that is, the capacitor may have excessive negative charges on one plate and a deficiency of negative charges on the other plate (positively charged).
- C. The electrical energy of a charged capacitor is stored in the dielectric between the conducting plates.
- D. A capacitor may be charged or discharged through a resistor.
- E. The larger the capacitor value in capacitance, and the larger the resistance value in ohms, the longer it will take the capacitor to charge or discharge.
- F. When a capacitor is charged or discharged through a resistor, the circuit is often called a resistive capacitive (RC) circuit.
- G. RC circuits are frequently used in timing applications, and to suppress voltage spikes from inductors.
- H. The unit of measure for capacitance is the farad.

(NOTE: Because one farad of capacity is very large, capacity values are expressed as micro-farads ( $\mu F$ ), this is one millionth of a farad.)

## INFORMATION SHEET

### XXVI. Switches (Transparencies 15&16)

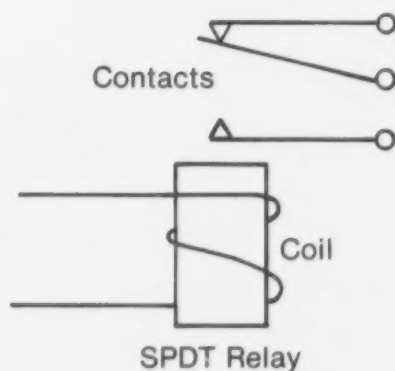
- A. The most basic mechanical switch is one that either closes or opens a circuit, and is called a single-pole, single-throw switch (SPST switch).
- B. Switches come in all sorts of configurations and may have many poles or contacts.
- C. Multi-throw switches offer circuit alternatives such as turning on high or low beam lights.

### XXVII. Electromechanical relays

- A. An inductor or coil of wire may be incorporated into a mechanical switch to form an electromechanical relay, usually simply called a relay.
- B. Relays allow a small control current to pass through the coil, the relay contacts open or close, opening or completing a high power circuit.
- C. Relays may be made in several switch configurations.

Example: SPST, SPDT, DPDT, 3PDT, etc. (Figure 2)

FIGURE 2      **Symbol for a Relay**



- D. A special high-power relay is called a solenoid.
- E. When current passes through the solenoid coil, the soft iron core is pulled into the coil by magnetic force.

## INFORMATION SHEET

### XXVIII. Schematic diagram (Transparency 17)

- A. Schematic diagrams are drawings made up of symbols to represent circuit components.
- B. Schematic diagrams are used to show much circuit information in limited space.
- C. With practice, schematic diagrams become easy to follow and the physical circuit easy to visualize.

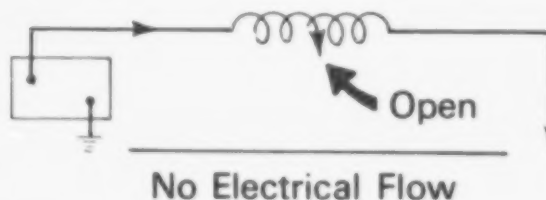
### XXIX. Scientific notation and metric prefixes (Transparency 18)

- A. Scientific notation or powers of ten convey fractions or multiples of basic units of volts, amps, or ohms.
- B. It is common practice to use names and symbols to represent commonly occurring powers of ten.
- C. One reason for using powers of ten is that it simplifies computations.
- D. In multiplication the powers of ten are added.
- E. In division the powers of ten are subtracted.

### XXX. Troubleshooting an open circuit

- A. An open circuit means that there is a break in the circuit, and there is no longer a path for current to flow. (Figure 3)

FIGURE 3



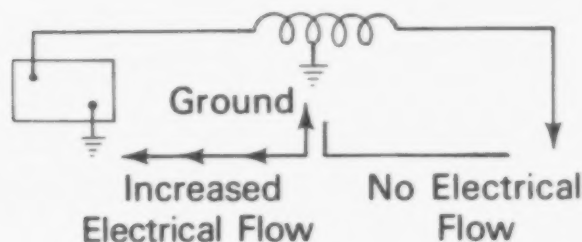
- B. In a series circuit, an open will stop all current flow, but in a parallel circuit, an open will affect only the branch where the open is located.
- C. One method of finding an open is to use a jumper wire to bypass a suspected trouble spot; if the jumper wire makes the circuit operational, the open is in the part of the circuit that was jumped.
- D. A continuity check with an ohmmeter or a self-powered test light is another way to check for an open, but be sure the circuit has first been disconnected from its voltage source.

## INFORMATION SHEET

### XXXI. Troubleshooting a short to ground

- A. A short to ground interrupts the normal current path in a circuit, and creates another path through a ground such as the chassis.
- B. Because a short to ground creates low resistance, a large current flow results, and it usually opens protection devices in the circuit, and blows a fuse, opens a fusible link, or cycles a circuit breaker on and off. (Figure 4)

FIGURE 4



- C. In circuits that have no fuse, a short to ground is dangerous because it may burn wire, and even produce flames.
- D. A test light can be used to locate a short to ground by putting the test light in place of the fuse.
- E. With the test light installed, disconnect circuit components in a logical order, and when the test light goes out, it indicates the trouble spot.
- F. A circuit breaker and a compass can also be used to locate a short to ground by removing the fuse, and connecting the circuit breaker to the fuse terminals.
- G. As the circuit heats and cools, the circuit breaker will open and close, and by moving the compass along the circuit, the point where there is no current flow that can be isolated because the compass needle will stop deflecting.

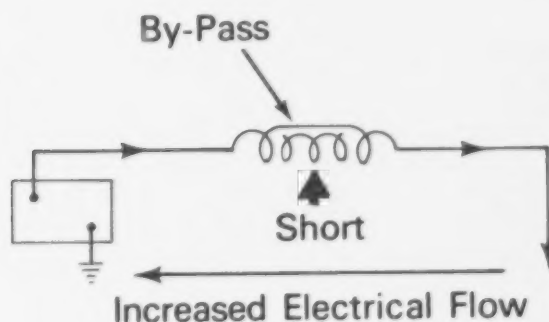
(NOTE: A compass will show a deflection even through sheet metal trim panels because of the magnetic field set up around the conductor when current flows through it.)

## INFORMATION SHEET

### XXXII. Troubleshooting shorts into another circuit

- A. A short to another circuit is usually caused when insulation breaks off wires, causing two bare wires to touch.
- B. A short into another circuit can also be caused by a damaged wiring harness.
- C. A short into another circuit can actually create new circuits, and cause strange things to happen. (Figure 5)

FIGURE 5



Example: If a series circuit shorts into a parallel circuit, the series circuit becomes a parallel circuit with less resistance. This creates additional current flow and sometimes opens circuit protection devices.

- D. Shorts into the voltage of another circuit can be difficult to find, and require isolating the problem systematically.
- E. Look for bare wires that are touching, remove fuses to isolate the problem, and make voltage checks at logical points in the circuits.
- F. A test light can be used to check for voltage along a circuit, but NEVER use a test light on circuits that contain solid-state components which could be damaged.

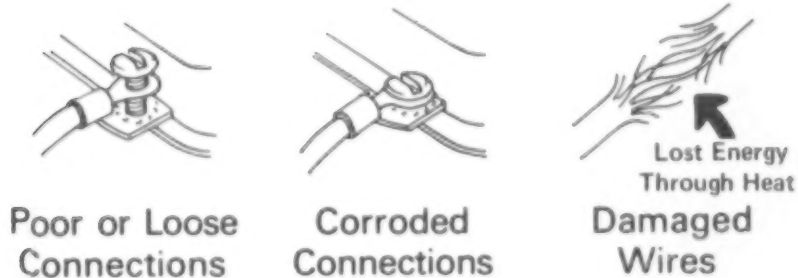
(NOTE: Circuits with solid state components should be tested with a digital voltmeter or multimeter that has a 10-megaohm impedance or higher.)

## INFORMATION SHEET

## XXXIII. Troubleshooting high-resistance problems

- A. High-resistance problems reduce current flow in a circuit, and can cause lamps to dim or flicker, or result in components that don't work at all.
- B. High-resistance problems can be caused by damaged wires, but frequently will be the result of connectors that are corroded, dirty, or loose. (Figure 6)

FIGURE 6



- C. High-resistance problems are sometimes the most difficult to find, and test instruments are important in high-resistance troubleshooting.
- D. High-resistance problems are frequently ground problems, and guidelines for troubleshooting more complex high-resistance problems are included in service manuals.

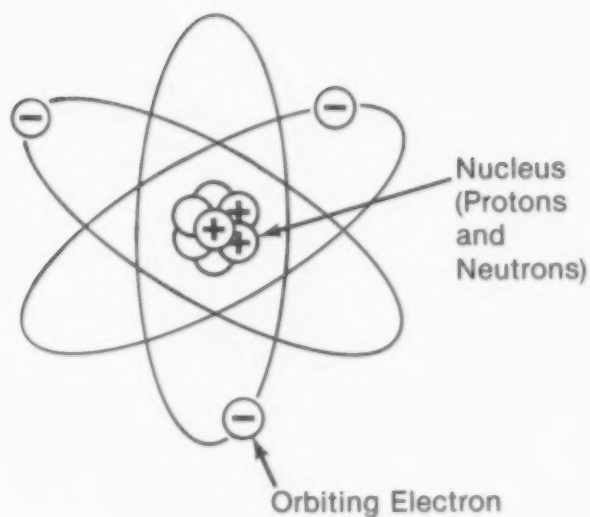
# Simple Atom

This simple atom has:

3 Protons

4 Neutrons

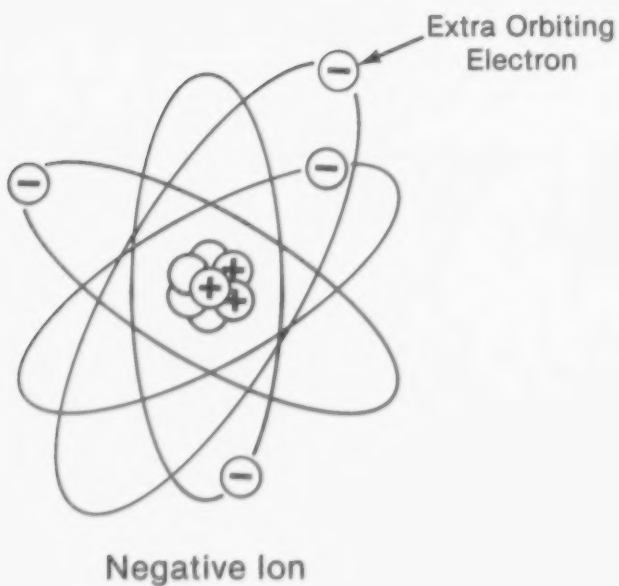
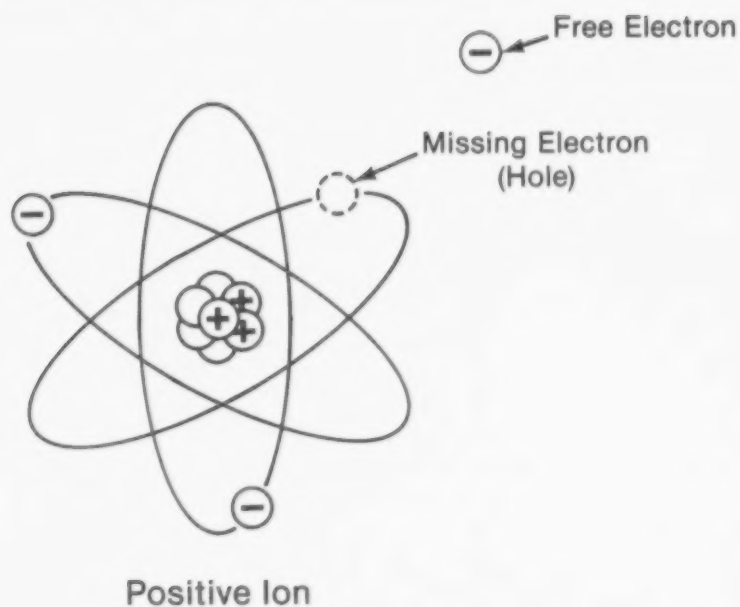
3 Electrons



- ⊖ Electrons have a *negative* electrical charge
- ⊕ Protons have a *positive* electrical charge
- Neutrons have *no* electrical charge

This atom has no net electrical charge since the negative charge of the electrons equal the positive charge of the protons

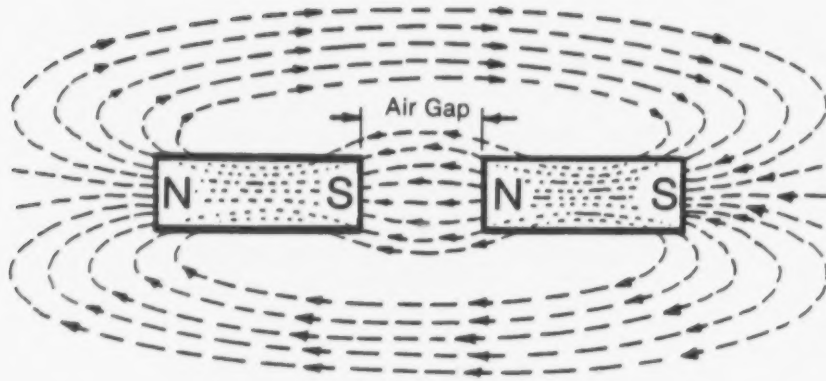
## Electron Loss and Gain



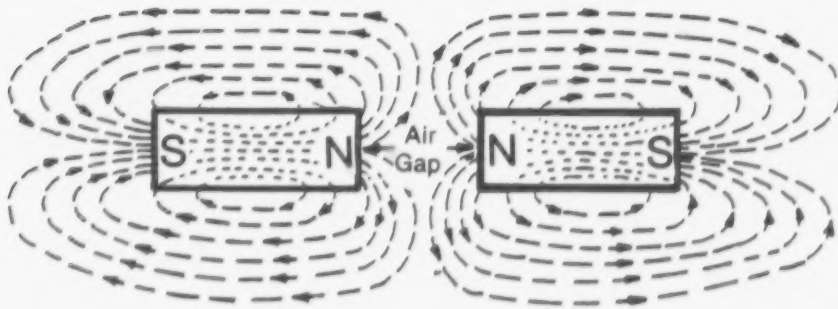
Under certain conditions an atom may lose an orbiting electron or may gain an extra orbiting electron



# Positive and Negative Charges

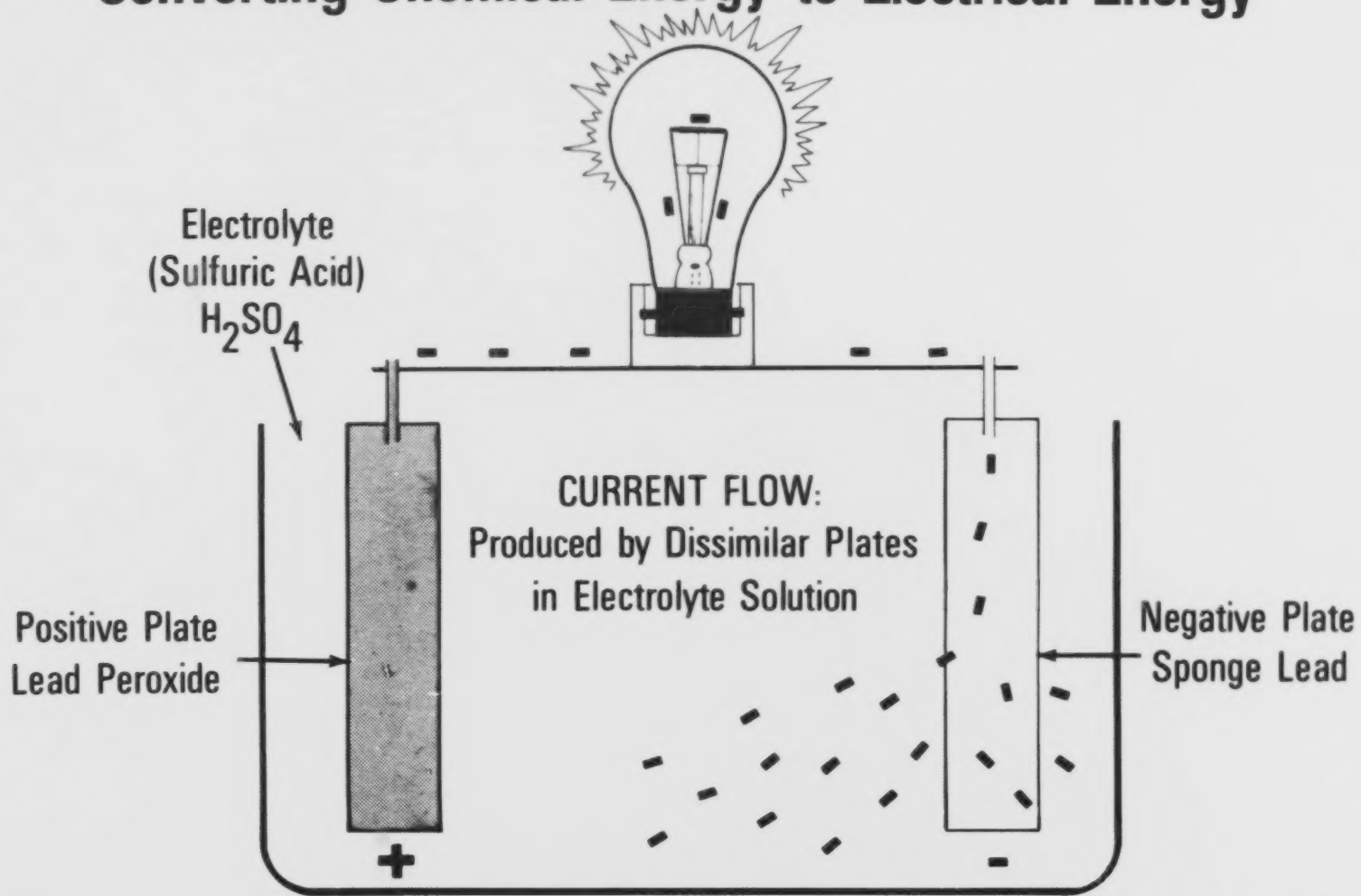


Unlike Poles Attract

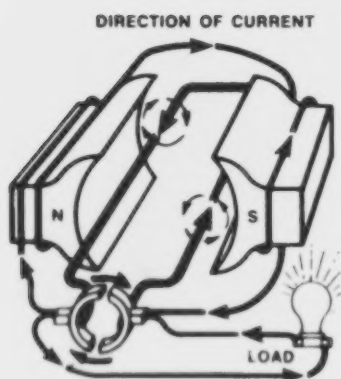


Like Poles Repel

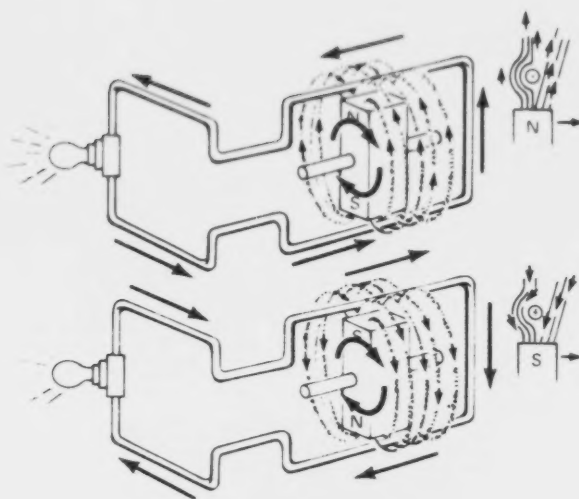
## Converting Chemical Energy to Electrical Energy



# Differences in Alternator and Generator



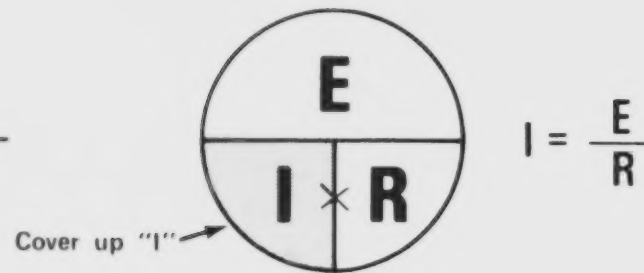
**Generator**



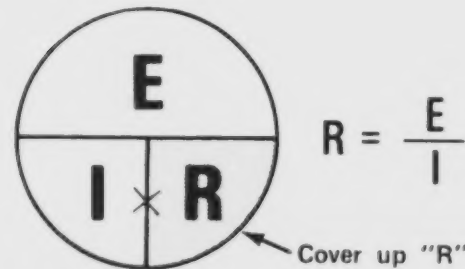
**Alternator**

# Ohm's Law

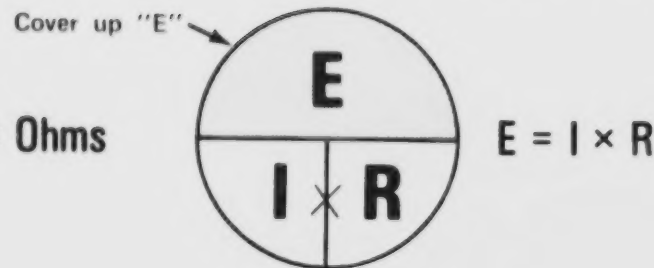
$$\text{Amperes} = \frac{\text{Volts}}{\text{Ohms}}$$



$$\text{Ohms} = \frac{\text{Volts}}{\text{Amperes}}$$

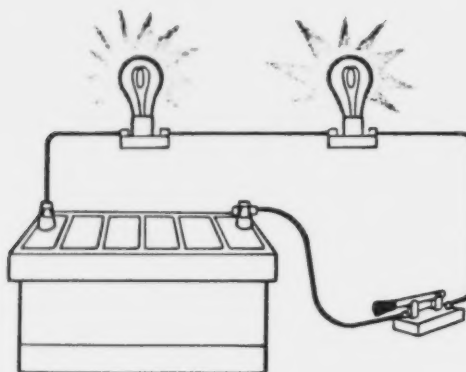


$$\text{Volts} = \text{Amperes} \times \text{Ohms}$$

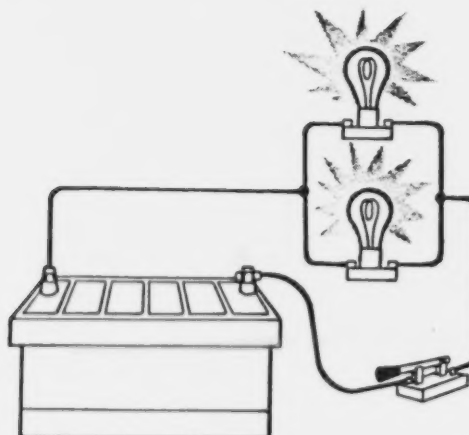


# Types of Circuits

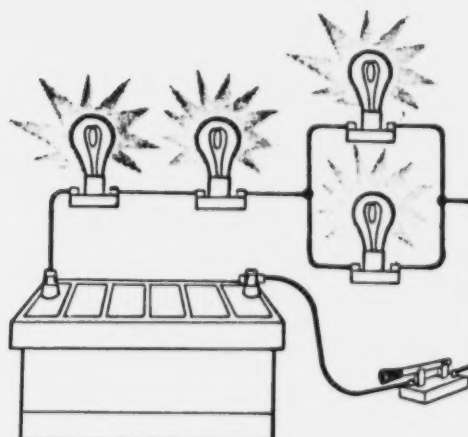
**Series  
Circuit**



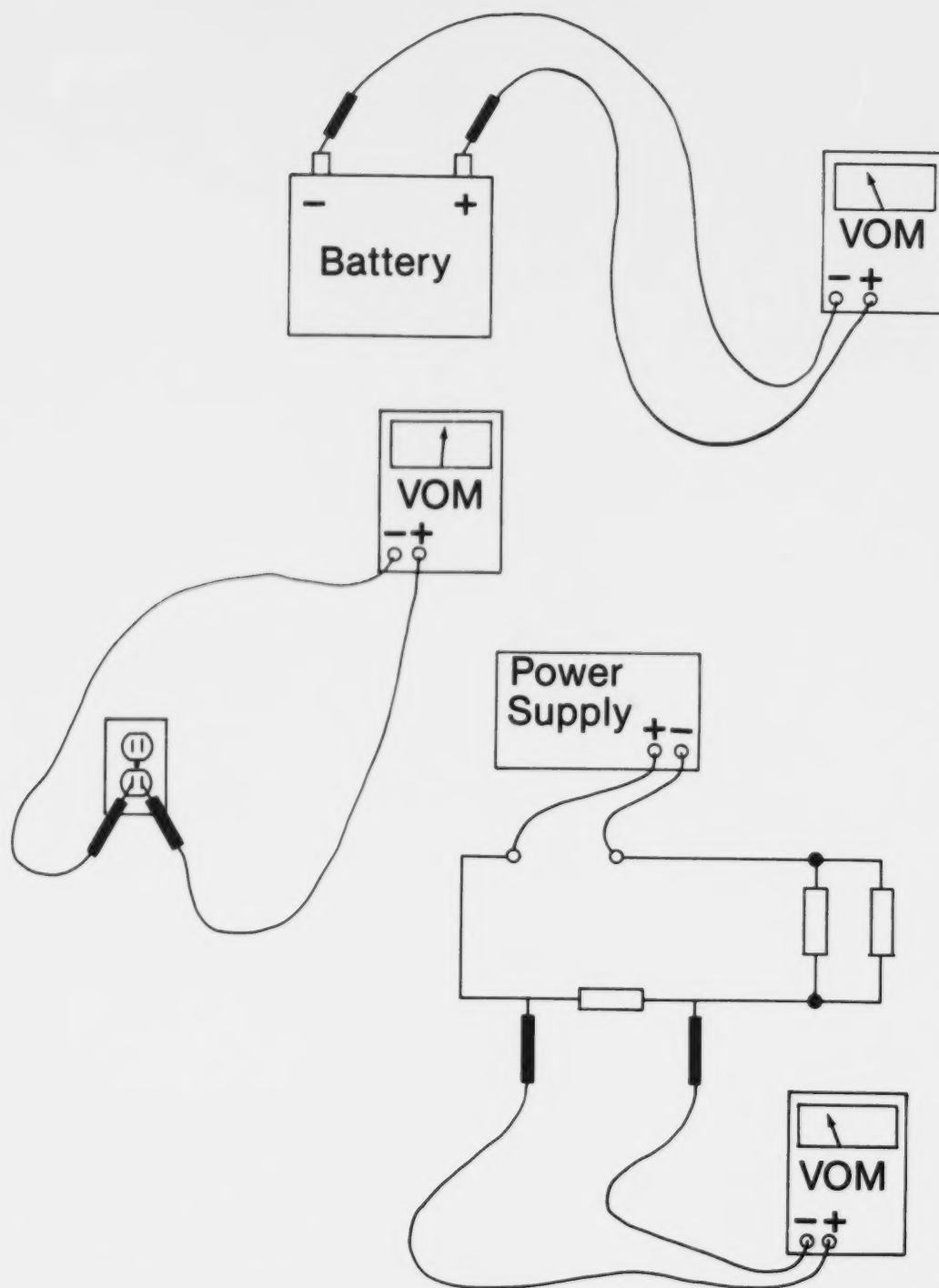
**Parallel  
Circuit**



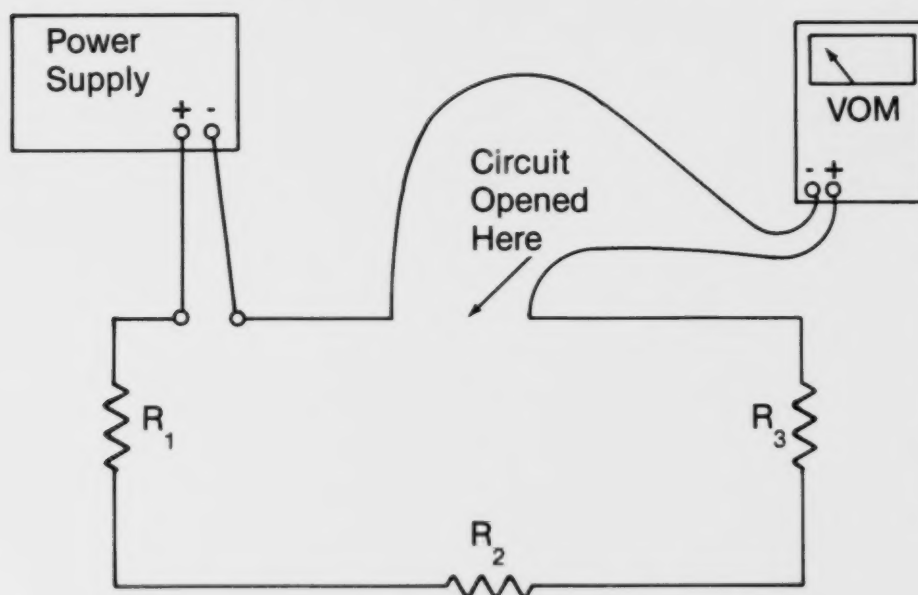
**Series-Parallel  
Circuit**



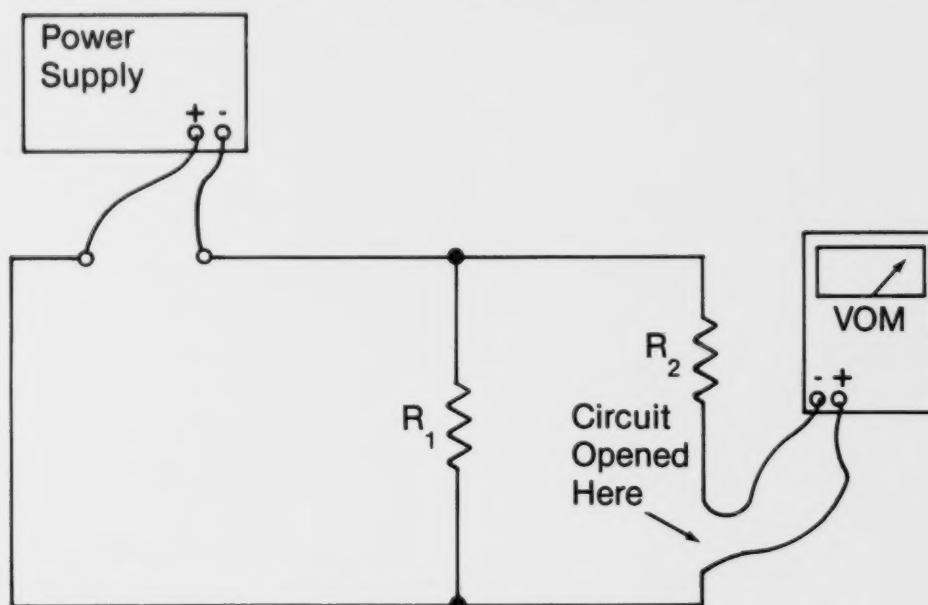
# Voltage Measurements



# Current Measurements



Measuring Amperage in Series Circuits



Measuring Amperage in Parallel Circuits

## Resistance Measurements



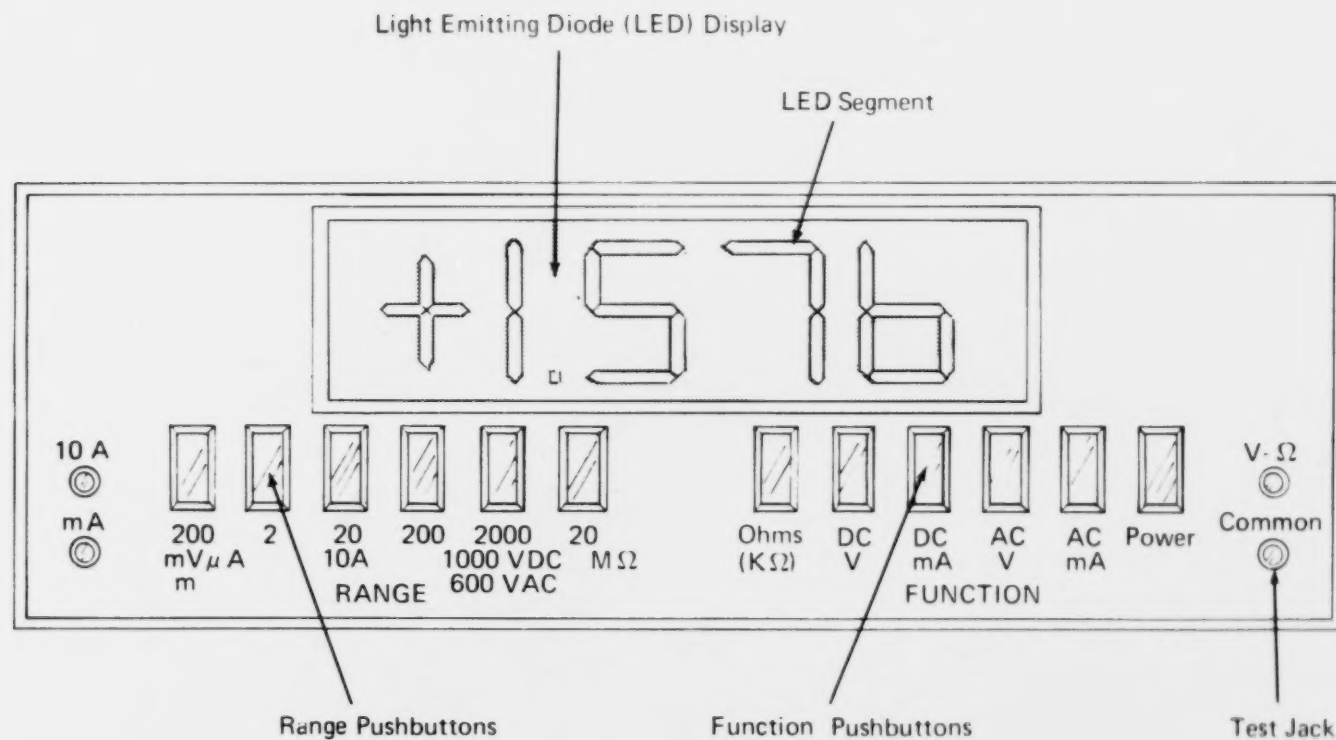
Isolating Component by Removing One Lead



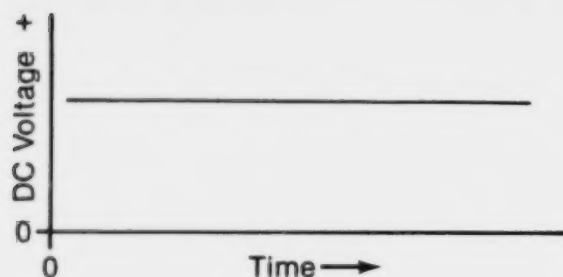
Isolating Component by Removing All Leads



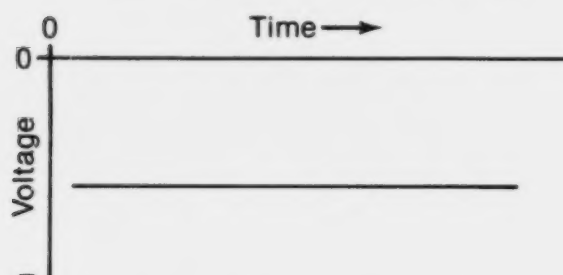
# DVOM



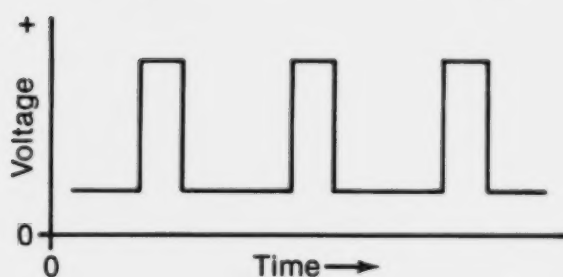
# Types of Direct Current



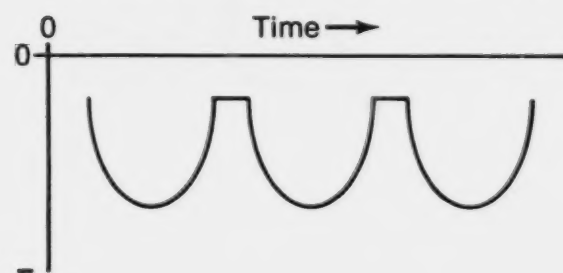
Positive Linear DC Voltage



Negative Linear DC Voltage

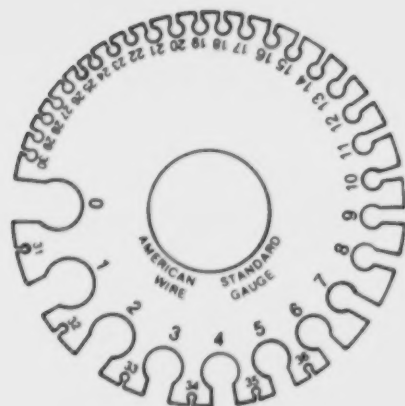


Positive Pulsating DC Voltage



Negative Pulsating DC Voltage

# Standard Copper Wire Gauge Sizes

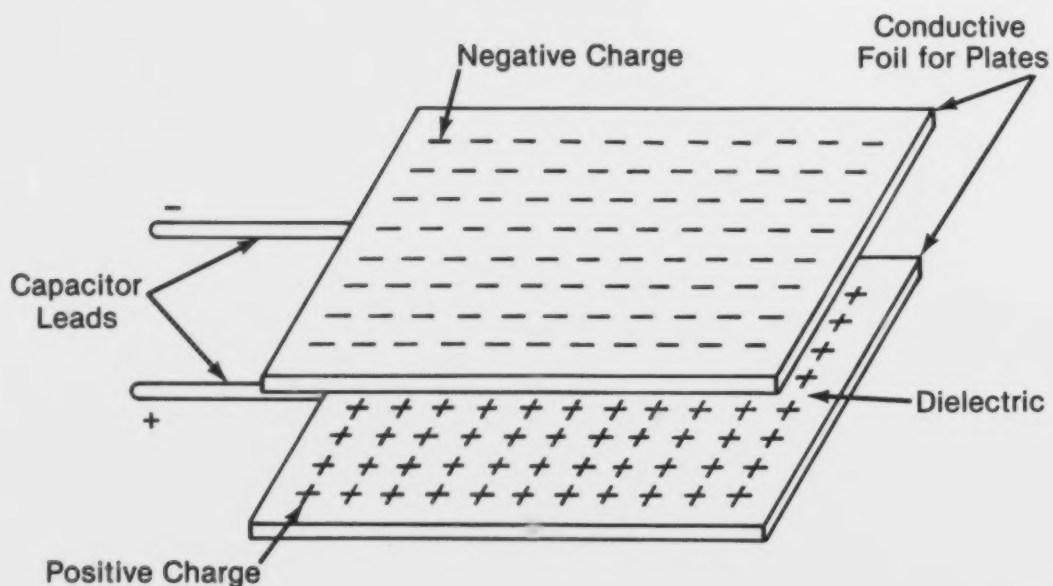


AMERICAN STANDARD WIRE GAUGE

| GAUGE NO. | DIAMETER, MILS | CIRCULAR-MIL AREA | OHMS PER 1,000 FT OF COPPER WIRE AT 25°C* | GAUGE NO. | DIAMETER, MILS | CIRCULAR-MIL AREA | OHMS PER 1,000 FT OF COPPER WIRE AT 25°C* |
|-----------|----------------|-------------------|-------------------------------------------|-----------|----------------|-------------------|-------------------------------------------|
| 1         | 289.3          | 83,690            | 0.1264                                    | 21        | 28.46          | 810.1             | 13.05                                     |
| 2         | 257.6          | 66,370            | 0.1593                                    | 22        | 25.35          | 642.4             | 16.46                                     |
| 3         | 229.4          | 52,640            | 0.2009                                    | 23        | 22.57          | 509.5             | 20.76                                     |
| 4         | 204.3          | 41,740            | 0.2533                                    | 24        | 20.10          | 404.0             | 26.17                                     |
| 5         | 181.9          | 33,100            | 0.3195                                    | 25        | 17.90          | 320.4             | 33.00                                     |
| 6         | 162.0          | 26,250            | 0.4028                                    | 26        | 15.94          | 254.1             | 41.62                                     |
| 7         | 144.3          | 20,820            | 0.5080                                    | 27        | 14.20          | 201.5             | 52.48                                     |
| 8         | 128.5          | 16,510            | 0.6405                                    | 28        | 12.64          | 159.8             | 66.17                                     |
| 9         | 114.4          | 13,090            | 0.8077                                    | 29        | 11.26          | 126.7             | 83.44                                     |
| 10        | 101.9          | 10,380            | 1.018                                     | 30        | 10.03          | 100.5             | 105.2                                     |
| 11        | 90.74          | 8,234             | 1.284                                     | 31        | 8.928          | 79.70             | 132.7                                     |
| 12        | 80.81          | 6,530             | 1.619                                     | 32        | 7.950          | 63.21             | 167.3                                     |
| 13        | 71.96          | 5,178             | 2.042                                     | 33        | 7.080          | 50.13             | 211.0                                     |
| 14        | 64.08          | 4,107             | 2.575                                     | 34        | 6.305          | 39.75             | 266.0                                     |
| 15        | 57.07          | 3,257             | 3.247                                     | 35        | 5.615          | 31.52             | 335.0                                     |
| 16        | 50.82          | 2,583             | 4.094                                     | 36        | 5.000          | 25.00             | 423.0                                     |
| 17        | 45.26          | 2,048             | 5.163                                     | 37        | 4.453          | 19.83             | 533.4                                     |
| 18        | 40.30          | 1,624             | 6.510                                     | 38        | 3.965          | 15.72             | 672.6                                     |
| 19        | 35.89          | 1,288             | 8.210                                     | 39        | 3.531          | 12.47             | 848.1                                     |
| 20        | 31.96          | 1,022             | 10.35                                     | 40        | 3.145          | 9.88              | 1,069                                     |

\*20 to 25 C or 68 to 77 F is considered average room temperature

# Capacitor



A capacitor is two conducting plates separated by a dielectric.

A dielectric is an insulator such as air, plastic, mica, paper, etc.

Capacitors hold charge

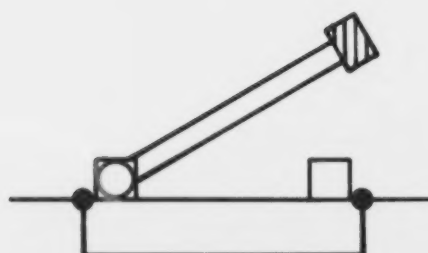
Capacitor symbol



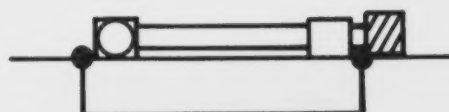
Commercial capacitors may look like any of these



# Basic Switch Single-Pole, Double-Throw (SPST Switch)



SPST Switch Open



SPST Switch Closed

## Symbols



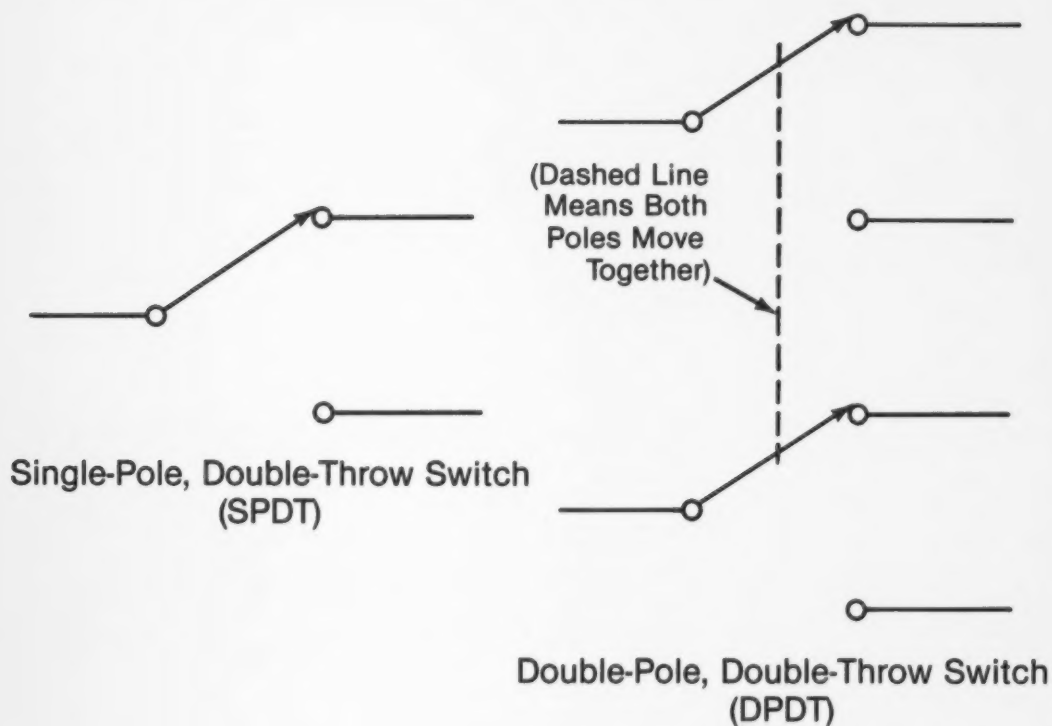
or



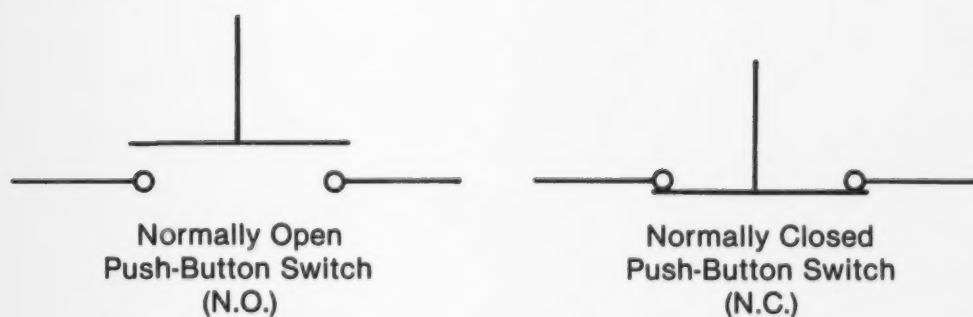
or



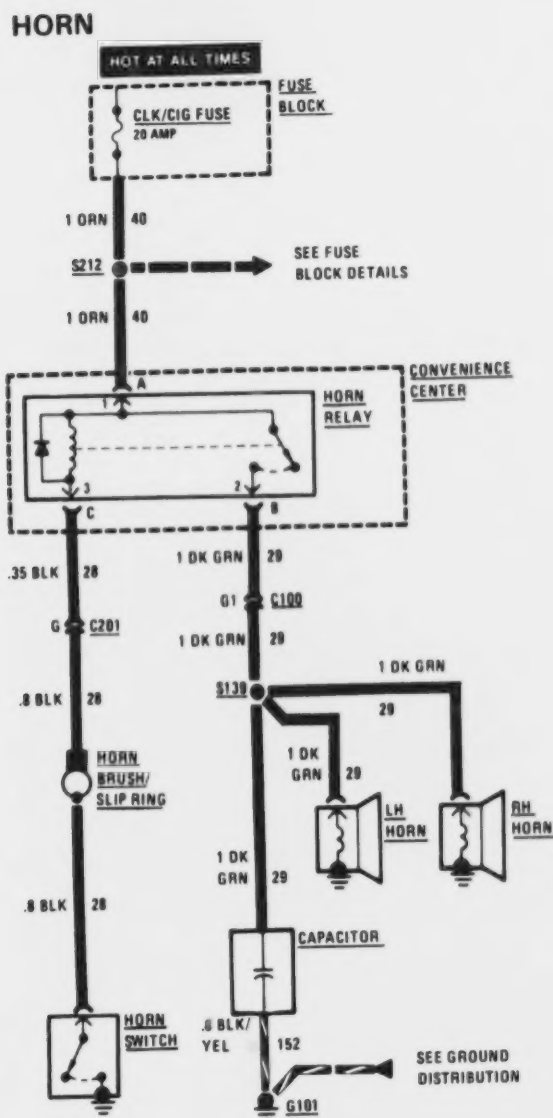
# Multiple Contact Switches



## Push-Button Switches



# Schematic Diagram



Courtesy Chevrolet Division, General Motors Corporation

## Metric Prefixes

|                    |       |    |              |
|--------------------|-------|----|--------------|
| $1\ 000\ 000=10^6$ | mega  | M  | one million  |
| $1\ 000=10^3$      | kilo  | k  | one thousand |
| $100=10^2$         | hecto | h  | one hundred  |
| $10=10$            | deka  | da | ten          |

---

|                      |       |       |                |
|----------------------|-------|-------|----------------|
| $0.1=10^{-1}$        | deci  | d     | one tenth      |
| $0.01=10^{-2}$       | centi | c     | one hundredth  |
| $0.001=10^{-3}$      | milli | m     | one thousandth |
| $0.000\ 001=10^{-6}$ | micro | $\mu$ | one millionth  |



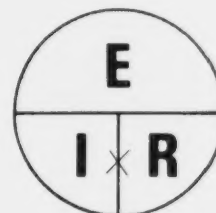
# AUTOMOTIVE DC ELECTRONICS UNIT III

## ASSIGNMENT SHEET #1 — CALCULATE VOLTAGE USING OHM'S LAW

Directions: Use the flip side of this assignment sheet as a scratch pad, and calculate voltage for the following problems. Reference your calculations by number so your math can be checked by your instructor.

$$E = I \times R$$

| 1. | Amperes | Ohms   | Volts |
|----|---------|--------|-------|
| a. | 0.005   | 16,000 | _____ |
| b. | 20      | 15     | _____ |
| c. | 5       | 365    | _____ |
| d. | 0.023   | 6.3    | _____ |
| e. | 7.5     | 1.6    | _____ |



2. A relay requires a current of 0.050 amperes to close its switch contacts. Its coil has a resistance of 240 ohms. How much voltage is needed?

Answer: \_\_\_\_\_

3. How much voltage must be applied to the 50-ohm heating element of a soldering iron that requires a current of 2.3 amperes to reach proper temperature?

Answer: \_\_\_\_\_

4. A transistor radio with an internal resistance of 200 ohms requires a current of 0.03 amperes for its operation. What battery voltage is needed?

• Answer: \_\_\_\_\_

5. A light bulb with a resistance of 10 ohms needs a 1.2 ampere current for full brilliancy. Calculate the voltage required.

Answer: \_\_\_\_\_

6. Calculate the battery voltage needed to drive a current of 150 amperes through the starter of a car. The starter's resistance is 0.08 ohms.

Answer: \_\_\_\_\_

## AUTOMOTIVE DC ELECTRONICS UNIT III

### ASSIGNMENT SHEET #2 — CALCULATE CURRENT FLOW IN AMPERES USING OHM'S LAW

Directions: Use the flip side of this assignment sheet as a scratch pad, and calculate amperage for the following problems. Reference your calculations by number so your math can be checked by your instructor.

$$I = \frac{E}{R}$$

| 1. | Amperes | Ohms | Amperes |
|----|---------|------|---------|
| a. | 0.2     | 16   | _____   |
| b. | 6       | 18   | _____   |
| c. | 12.6    | 3.5  | _____   |
| d. | 12      | 0.5  | _____   |
| e. | 9       | 55   | _____   |



2. Calculate the amperage in a circuit with a 4-ohm resistor when connected to a 12-volt battery.

Answer: \_\_\_\_\_

3. A transistor radio with an internal resistance of 600 ohms is operated with a 12-volt battery. How much current must the battery supply?

Answer: \_\_\_\_\_

4. A soldering iron has a resistance of 200 ohms. How much current will it draw from a 115-volt line?

Answer: \_\_\_\_\_

5. The starter of an automobile has a resistance of 0.12 ohms. How much current must a 12.6-volt storage battery supply to start the car?

Answer: \_\_\_\_\_

6. A fan motor in an automobile air conditioner has an internal resistance of 180 ohms and a 120-volt battery. What will be the amperage draw of the motor?

Answer: \_\_\_\_\_

## AUTOMOTIVE DC ELECTRONICS UNIT III

### ASSIGNMENT SHEET #3 — CALCULATE RESISTANCE USING OHM'S LAW

Directions: Use the flip side of this assignment sheet as a scratch pad, and calculate resistance for the following problems. Reference your calculations by number so your math can be checked by your instructor.

$$R = \frac{E}{I}$$

| 1. | Volts | Amperes | Ohms  |
|----|-------|---------|-------|
| a. | 115   | 0.30    | _____ |
| b. | 12    | 4.0     | _____ |
| c. | 6     | 2.5     | _____ |
| d. | 9.6   | 0.25    | _____ |
| e. | 10.0  | 160     | _____ |



2. A 12-volt battery causes an electrical current of 1.25 amperes to flow through a car radio. Calculate the radio's internal resistance.

Answer: \_\_\_\_\_

3. Calculate the internal resistance of an ignition coil with a current draw of 7.5 amperes of 12 volts.

Answer: \_\_\_\_\_

4. Calculate the resistance of an automobile headlight that needs a current of 3 amperes and a supply voltage of 12.6 volts.

Answer: \_\_\_\_\_

5. An automobile horn has a current draw of 4.8 amperes with a battery voltage of 12.4 volts. What is the internal resistance of the horn?

Answer: \_\_\_\_\_

6. An ignition resistance unit supplies the ignition system with 2.7 amperes of current at 9 volts. What is the ohms of resistance in the unit?

Answer: \_\_\_\_\_

## AUTOMOTIVE DC ELECTRONICS UNIT III

### ANSWERS TO ASSIGNMENT SHEETS

#### Assignment Sheet #1

1.
  - a. 80 volts
  - b. 300 volts
  - c. 1825 volts
  - d. 0.1449 volts
  - e. 12 volts
2. 12 volts
3. 115 volts
4. 6 volts
5. 12 volts
6. 12 volts

#### Assignment Sheet #2

1.
  - a. 0.013 amperes
  - b. 0.33 amperes
  - c. 3.6 amperes
  - d. 24 amperes
  - e. 0.164 amperes
2. 3.0 amperes
3. 0.02 amperes
4. 0.575 amperes
5. 105 amperes
6. 0.067 amperes

#### Assignment Sheet #3

1.
  - a. 383.33 ohms
  - b. 3 ohms
  - c. 2.4 ohms
  - d. 38.4 ohms
  - e. 0.0625 ohms
2. 9.6 ohms
3. 1.6 ohms
4. 4.2 ohms
5. 2.583 ohms
6. 3.333 ohms

## AUTOMOTIVE DC ELECTRONICS UNIT III

### JOB SHEET #1 — MEASURE VOLTAGE DROPS IN A SERIES CIRCUIT

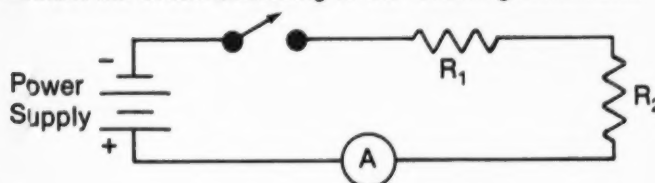
#### A. Equipment and materials

1. 0 to 12 volt power supply
2. One switch (SPST)
3. Two resistors of the same value (100 ohm)
4. One resistor of a different value (50 ohm)
5. DVOM (minimum impedance of 10 megohms)

(NOTE: Your instructor will give you the value of voltage and the value of resistors to use.)

#### B. Procedure

1. Put on safety glasses.
2. Connect the circuit according to the following schematic.



☐ Have your instructor check your circuit.

3. Close the switch.
4. Use the voltmeter to read and record the following:

$E_a =$  \_\_\_\_\_

$V_{R1} =$  \_\_\_\_\_

$V_{R2} =$  \_\_\_\_\_

$V_{R3} =$  \_\_\_\_\_

5. Add the voltage drops across the three resistors and compare the sum with the amount of applied voltage.

**JOB SHEET #1**

6. Compare the voltage drops across  $R_1$ ,  $R_2$ , and  $R_3$  having the same value of ohms and with the voltage drop across the other resistor.

(NOTE: Discuss with your instructor how applied voltage distributes itself across resistances of unequal or of equal value.)

7. Identify the most negative point in the circuit.
8. Return equipment and materials to proper storage.

## AUTOMOTIVE DC ELECTRONICS UNIT III

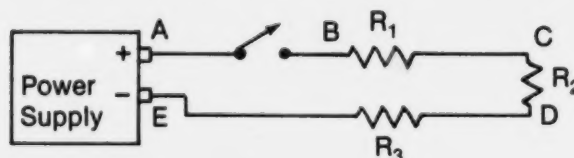
### JOB SHEET #2 — ANALYZE CURRENT VALUES IN A SERIES CIRCUIT

#### A. Equipment and materials

1. 0 to 12 volt power supply
2. One switch (SPST)
3. Two resistors:  $R_1 = 4.7K$ , 1 watt;  $R_2 = 1K$ , 1W.
4. Ammeter (or multimeter)
5. Voltmeter
6. Ohmmeter
7. Electrical bread board
8. Safety glasses

#### B. Procedure

1. Put on safety glasses.
2. Measure and record the ohms value of the two resistors.
3. Connect a circuit as shown in the following schematic.



☐ Have your instructor check your circuit.

4. Close the switch and adjust the power supply output to 12 volts.
5. Use the voltmeter to measure the following voltages:  
 $V_{R1} = \underline{\hspace{2cm}}$   $V_{R2} = \underline{\hspace{2cm}}$   $E_a = \underline{\hspace{2cm}}$
6. Read and record the ammeter indication  $I = \underline{\hspace{2cm}}$
7. Disconnect the circuit by opening the switch.

## JOB SHEET #2

8. Use Ohm's law and compute:

$$I_{R1} = \underline{\hspace{1cm}} \quad I_{R2} = \underline{\hspace{1cm}} \quad I_T = \underline{\hspace{1cm}} \quad \left( \frac{I_T = E_a}{R_T} \right)$$

9. Compare the values of the various current computations, and explain the differences, if any, in these values.
10. Return equipment and materials to their proper storage area.



## AUTOMOTIVE DC ELECTRONICS UNIT III

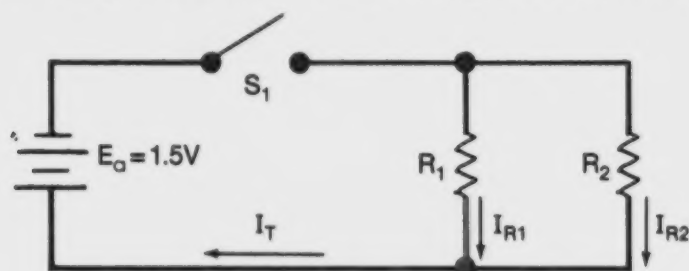
### JOB SHEET #3 — MEASURE VOLTAGE, CURRENT, AND RESISTANCE IN A PARALLEL CIRCUIT

#### A. Equipment and materials

1. 1.5 battery or equivalent
2. Two small resistors of equal value or two small lamps
3. VOM or voltmeter
4. VOM or ammeter
5. Switch
6. Wire to complete circuit
7. Electrical bread board
8. Safety glasses

#### B. Procedure

1. Put on safety glasses.
2. Construct a parallel resistive circuit according to the schematic below.



☐ Have your instructor check your circuit.

3. Close switch  $S_1$ .
4. Measure and record applied voltage ( $E_a$ ).
5. Measure and record voltage across  $R_1$ , and across  $R_2$ .
6. Compare recorded voltages. Are they all equal? Explain why.

## JOB SHEET #3

7. Open switch  $S_1$ .
8. Connect ammeter in series with  $R_1$ .
9. Close switch  $S_1$  and read and record current ( $I_{R1}$ ).
10. Open switch  $S_1$ .
11. Disconnect ammeter from  $R_1$  branch and connect it in series with  $R_2$ .
12. Close switch  $S_1$ , and read and record current ( $I_{R2}$ ).
13. Open switch  $S_1$ .
14. Disconnect ammeter from  $R_1$  branch, and connect it in series with the voltage source ( $E_a$ ) and switch  $S_1$ .
15. Close switch  $S_1$  and read and record main current ( $I_T$ ).
16. Open switch  $S_1$ .
17. Are recorded currents  $I_{R1}$  and  $I_{R2}$  equal? (NOTE: Explain why or why not.)
18. Add  $I_{R1}$  and  $I_{R2}$ . Does the sum equal  $I_T$ ? (NOTE: Explain why or why not.)
19. Close switch; if lamps were used for  $R_1$  and  $R_2$ , note that both lamps are glowing.
20. Disconnect  $R_2$  from circuit.
21. Record ammeter indication, and, if  $R_1$  and  $R_2$  are lamps, note any changes in  $R_1$  operation when  $R_2$  (lamp) was removed.
22. Replace  $R_2$ , and remove  $R_1$  from circuit.
23. Record ammeter indication, and note any changes in  $R_2$  operation, if applicable.
24. Reconnect  $R_1$ .
25. Using voltmeter read and record applied voltage ( $E_a$ ),  $E_{R1}$ , and  $E_{R2}$ .
26. Using measured  $E_a$  and  $I_T$ , compute total resistance of the circuit ( $R_T$ ).
27. Using measured voltage and current values, compute  $R_1$  and  $R_2$ , and from these figures compute  $R_T$ .
28. If  $R_1$  and  $R_2$  are lamps, explain changes in lamp operation when one lamp was removed from the circuit.
29. Return equipment and materials to proper storage area.

## AUTOMOTIVE DC ELECTRONICS UNIT III

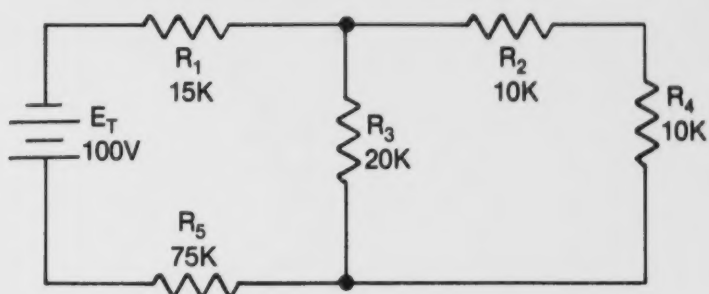
### JOB SHEET #4 — TROUBLESHOOT SERIES-PARALLEL CIRCUITS

**A. Equipment and materials**

1. Multimeter
2. Electrical bread board
3. Resistors — 2, 10 Kohms
4. Resistor — 20 Kohms
5. Resistor — 15 Kohms
6. Resistor — 75 Kohms
7. DC power supply — Capable of 120 VDC

**B. Procedure**

1. Put on safety glasses.
2. Connect the series-parallel circuit as shown below.



☐ Have your instructor check your circuit.

3. Look back over Job Sheets #1, #2, and #3 to familiarize yourself with the voltages, current, and resistance values of the circuit above.
4. Ask the instructor to insert a "trouble" in the figure above.
5. Troubleshoot the circuit using correct troubleshooting procedures.

**JOB SHEET #4**

6. Indicate the problem and explain the procedures used to locate the "trouble."

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(NOTE: At this point, the instructor should check student work and discuss troubleshooting procedures used.)

7. Repeat steps 3 through 5 for each additional "trouble" the instructor adds.
8. Indicate the problems and explain procedures used to locate them.

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9. Return equipment and materials to their proper storage location.

# AUTOMOTIVE DC ELECTRONICS UNIT III

## PRACTICAL TEST #1 JOB SHEET #1 — MEASURE VOLTAGE DROPS IN A SERIES

Student's name \_\_\_\_\_

Date \_\_\_\_\_

Evaluator's name \_\_\_\_\_

Attempt no. \_\_\_\_\_

Student instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

### PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

| The student:                                   | YES                         | NO                       |
|------------------------------------------------|-----------------------------|--------------------------|
| 1. Wore safety glasses.                        | 1. <input type="checkbox"/> | <input type="checkbox"/> |
| 2. Connected circuit properly.                 | 2. <input type="checkbox"/> | <input type="checkbox"/> |
| 3. Used DVOM properly.                         | 3. <input type="checkbox"/> | <input type="checkbox"/> |
| 4. Recorded circuit voltages properly.         | 4. <input type="checkbox"/> | <input type="checkbox"/> |
| 5. Calculated voltage drop properly.           | 5. <input type="checkbox"/> | <input type="checkbox"/> |
| 6. Compared voltage drop with applied voltage. | 6. <input type="checkbox"/> | <input type="checkbox"/> |
| 7. Returned tools and materials to storage.    | 7. <input type="checkbox"/> | <input type="checkbox"/> |

Evaluator's comments: \_\_\_\_\_

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## JOB SHEET #1 PRACTICAL TEST

### PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

|                             |                    |                          |                      |                   |
|-----------------------------|--------------------|--------------------------|----------------------|-------------------|
| Circuit Construction        | Good<br>4          | Acceptable<br>3          | Poor<br>2            | Unacceptable<br>1 |
| Use of Test Equipment       | Good<br>4          | Acceptable<br>3          | Poor<br>2            | Unacceptable<br>1 |
| Accomplishment of Procedure | Good<br>4          | Acceptable<br>3          | Poor<br>2            | Unacceptable<br>1 |
| Safety                      | Well Observed<br>4 | Acceptable Observed<br>3 | Poorly Observed<br>2 | Unacceptable<br>1 |

EVALUATOR'S COMMENTS: \_\_\_\_\_

#### PERFORMANCE EVALUATION KEY

- 4 — Skilled — Can perform job with no additional training.
- 3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
- 2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
- 1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

## AUTOMOTIVE DC ELECTRONICS UNIT III

### PRACTICAL TEST #2 JOB SHEET #2 — ANALYZE CURRENT VALUES IN A SERIES CIRCUIT

Student's name \_\_\_\_\_

Date \_\_\_\_\_

Evaluator's name \_\_\_\_\_

Attempt no. \_\_\_\_\_

Student instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

#### PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

| The student:                                      | YES                         | NO                       |
|---------------------------------------------------|-----------------------------|--------------------------|
| 1. Wore safety glasses.                           | 1. <input type="checkbox"/> | <input type="checkbox"/> |
| 2. Verified ohmic value of resistors.             | 2. <input type="checkbox"/> | <input type="checkbox"/> |
| 3. Connected circuit properly.                    | 3. <input type="checkbox"/> | <input type="checkbox"/> |
| 4. Made and recorded voltages properly.           | 4. <input type="checkbox"/> | <input type="checkbox"/> |
| 5. Analyzed circuit using Ohm's law.              | 5. <input type="checkbox"/> | <input type="checkbox"/> |
| 6. Made appropriate comparison of circuit values. | 6. <input type="checkbox"/> | <input type="checkbox"/> |
| 7. Returned tools and materials to storage.       | 7. <input type="checkbox"/> | <input type="checkbox"/> |

Evaluator's comments: \_\_\_\_\_

 \_\_\_\_\_  
 \_\_\_\_\_

## JOB SHEET #2 PRACTICAL TEST

### PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

|                             |                    |                          |                      |                   |
|-----------------------------|--------------------|--------------------------|----------------------|-------------------|
| Circuit Construction        | Good<br>4          | Acceptable<br>3          | Poor<br>2            | Unacceptable<br>1 |
| Use of Test Equipment       | Good<br>4          | Acceptable<br>3          | Poor<br>2            | Unacceptable<br>1 |
| Accomplishment of Procedure | Good<br>4          | Acceptable<br>3          | Poor<br>2            | Unacceptable<br>1 |
| Safety                      | Well Observed<br>4 | Acceptable Observed<br>3 | Poorly Observed<br>2 | Unacceptable<br>1 |

EVALUATOR'S COMMENTS: \_\_\_\_\_

#### PERFORMANCE EVALUATION KEY

- 4 — Skilled — Can perform job with no additional training.
- 3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
- 2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
- 1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)



## AUTOMOTIVE DC ELECTRONICS UNIT III

### PRACTICAL TEST #3 JOB SHEET #3 — MEASURE VOLTAGE, CURRENT, AND RESISTANCE IN A PARALLEL CIRCUIT

Student's name \_\_\_\_\_

Date \_\_\_\_\_

Evaluator's name \_\_\_\_\_

Attempt no. \_\_\_\_\_

Student instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

#### PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:

|                                               | YES                         | NO                       |
|-----------------------------------------------|-----------------------------|--------------------------|
| 1. Wore safety glasses.                       | 1. <input type="checkbox"/> | <input type="checkbox"/> |
| 2. Connected circuit properly.                | 2. <input type="checkbox"/> | <input type="checkbox"/> |
| 3. Measured and recorded applied voltage.     | 3. <input type="checkbox"/> | <input type="checkbox"/> |
| 4. Measured and recorded current properly.    | 4. <input type="checkbox"/> | <input type="checkbox"/> |
| 5. Measured and recorded resistance properly. | 5. <input type="checkbox"/> | <input type="checkbox"/> |
| 6. Made appropriate conclusions.              | 6. <input type="checkbox"/> | <input type="checkbox"/> |
| 7. Returned tools and materials to storage.   | 7. <input type="checkbox"/> | <input type="checkbox"/> |

Evaluator's comments: \_\_\_\_\_

---



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## JOB SHEET #3 PRACTICAL TEST

### PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

|                             |                    |                          |                      |                   |
|-----------------------------|--------------------|--------------------------|----------------------|-------------------|
| Circuit Construction        | Good<br>4          | Acceptable<br>3          | Poor<br>2            | Unacceptable<br>1 |
| Use of Test Equipment       | Good<br>4          | Acceptable<br>3          | Poor<br>2            | Unacceptable<br>1 |
| Accomplishment of Procedure | Good<br>4          | Acceptable<br>3          | Poor<br>2            | Unacceptable<br>1 |
| Safety                      | Well Observed<br>4 | Acceptable Observed<br>3 | Poorly Observed<br>2 | Unacceptable<br>1 |

EVALUATOR'S COMMENTS: \_\_\_\_\_

#### PERFORMANCE EVALUATION KEY

- 4 — Skilled — Can perform job with no additional training.
- 3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
- 2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
- 1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

## AUTOMOTIVE DC ELECTRONICS UNIT III

### PRACTICAL TEST #4 JOB SHEET #4 — TROUBLESHOOT SERIES-PARALLEL CIRCUITS

Student's name \_\_\_\_\_

Date \_\_\_\_\_

Evaluator's name \_\_\_\_\_

Attempt no. \_\_\_\_\_

Student instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

#### PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:

|                                                      | YES                         | NO                       |
|------------------------------------------------------|-----------------------------|--------------------------|
| 1. Wore safety glasses.                              | 1. <input type="checkbox"/> | <input type="checkbox"/> |
| 2. Connected circuit properly.                       | 2. <input type="checkbox"/> | <input type="checkbox"/> |
| 3. Identified trouble with correct procedure.        | 3. <input type="checkbox"/> | <input type="checkbox"/> |
| 4. Identified and explained problem.                 | 4. <input type="checkbox"/> | <input type="checkbox"/> |
| 5. Identified other troubles with correct procedure. | 5. <input type="checkbox"/> | <input type="checkbox"/> |
| 6. Returned tools and materials to storage.          | 6. <input type="checkbox"/> | <input type="checkbox"/> |

Evaluator's comments: \_\_\_\_\_

\_\_\_\_\_  
\_\_\_\_\_

## JOB SHEET #4 PRACTICAL TEST

### PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria: \_\_\_\_\_

|                             |                    |                          |                      |                   |
|-----------------------------|--------------------|--------------------------|----------------------|-------------------|
| Circuit Construction        | Good<br>4          | Acceptable<br>3          | Poor<br>2            | Unacceptable<br>1 |
| Use of Test Equipment       | Good<br>4          | Acceptable<br>3          | Poor<br>2            | Unacceptable<br>1 |
| Accomplishment of Procedure | Good<br>4          | Acceptable<br>3          | Poor<br>2            | Unacceptable<br>1 |
| Safety                      | Well Observed<br>4 | Acceptable Observed<br>3 | Poorly Observed<br>2 | Unacceptable<br>1 |

EVALUATOR'S COMMENTS: \_\_\_\_\_

#### PERFORMANCE EVALUATION KEY

- 4 — Skilled — Can perform job with no additional training.
- 3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
- 2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
- 1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

## AUTOMOTIVE DC ELECTRONICS UNIT III

### TEST

NAME \_\_\_\_\_

SCORE \_\_\_\_\_

1. Match terms related to automotive DC electronics with their correct definitions.

- |         |                                                                                                                                    |                |
|---------|------------------------------------------------------------------------------------------------------------------------------------|----------------|
| _____a. | Portable, chemical source of electricity                                                                                           | 1. Ion         |
| _____b. | Electronic component that stores energy in an electrostatic field                                                                  | 2. Voltage     |
| _____c. | Materials that pass electricity easily                                                                                             | 3. Insulators  |
| _____d. | The rate of flow of electrical charge, measured in amperes; the symbol is I                                                        | 4. Neutron     |
| _____e. | Atomic particles that have a negative charge                                                                                       | 5. Battery     |
| _____f. | Basic building blocks of matter                                                                                                    | 6. Proton      |
| _____g. | Electronic component that stores energy in a magnetic field                                                                        | 7. Inductors   |
| _____h. | Materials that do not pass electricity easily                                                                                      | 8. Capacitor   |
| _____i. | An atom that has gained or lost an electron                                                                                        | 9. Resistor    |
| _____j. | Atomic particle that has no electric charge                                                                                        | 10. Conductors |
| _____k. | Atomic particle with a positive electric charge                                                                                    | 11. Current    |
| _____l. | Electronic component that resists the flow of electricity, converts electrical energy to heat, unit is the ohm, symbol is $\Omega$ | 12. Elements   |
| _____m. | Electrical pressure that can force current to flow through resistance, unit is volt, symbols used are V and E                      | 13. Electrons  |

2. Select true statements concerning the nature of matter by placing an "X" beside each statement that is true.

- \_\_\_\_\_a. All matter is made up of basic building blocks called elements.
- \_\_\_\_\_b. There are over 100 naturally occurring elements such as oxygen, hydrogen, carbon, and iron.

## TEST

- \_\_\_\_c. Elements can combine to produce common forms of matter.
- \_\_\_\_d. Each element has its own unique atomic structure.
- \_\_\_\_e. An atom is made up of two parts, a dense nucleus and electrons that orbit the nucleus.
- \_\_\_\_f. The nucleus of an atom has two kinds of atomic particles, neutrons and protons.
- \_\_\_\_g. Electrons have a positive electrical charge.
- \_\_\_\_h. Protons have a negative electrical charge.
- \_\_\_\_i. Neutrons have both positive and negative charges.
- \_\_\_\_j. The negative electrical charge of an electron is the same size as the positive charge of a proton.
- \_\_\_\_k. In a normal atom there are as many orbiting electrons as protons in the nucleus.
- \_\_\_\_l. Under certain conditions, an atom may gain an extra electron or lose an orbiting electron.
- \_\_\_\_m. If an atom gains or loses an orbiting electron, the atom is no longer electrically neutral— the atom has become an *ion*.
- \_\_\_\_n. If an atom loses an orbiting electron, the atom has a net positive charge and is called a positive ion.
- \_\_\_\_o. An electron lost from an atom is called a lost electron.
- \_\_\_\_p. When an atom loses an electron the empty space left in the atom is called a slot.
- \_\_\_\_q. If an atom gains an extra orbiting electron, the atom has a net negative charge and is called a negative ion.
- \_\_\_\_r. The movement of electrons is considered electricity.

3. Solve problems concerning static electricity by answering the following questions.

- a. What is the easiest way to create static electricity?

Answer: \_\_\_\_\_

- b. Why is an awareness of static electricity necessary for automotive technicians?

Answer: \_\_\_\_\_

## TEST

4. Select true statements concerning dynamic electricity by placing an "X" beside each statement that is true.

- \_\_\_\_a. Dynamic or moving electrons are called active electrons.
- \_\_\_\_b. Electrons can quickly form an electric current if placed near positive ions; the positive charged ions attract the electrons which rush to fill the holes left by missing electrons.
- \_\_\_\_c. Electrons will be repelled by negative ions because *like charges repel* and *unlike charges attract*.
- \_\_\_\_d. Electric currents flow easily through metal wires called insulators.
- \_\_\_\_e. The best metals for electrical conductors are gold, silver, copper, and aluminum, and copper is the most commonly used electrical conductor.
- \_\_\_\_f. Electrical pressure supplied by a battery or other source can make current flow through a conducting path known as a loop.
- \_\_\_\_g. The electrical pressure that causes an electrical current to flow through a closed electrical path is called voltage.
- \_\_\_\_h. The unit of measure of electrical pressure is the volt.
- \_\_\_\_i. The measure of how much current flows through a conductor is the ampere.
- \_\_\_\_j. When an electrical resistance such as a light bulb is placed in the path of an electrical current, the measure of electrical resistance is the ohm.
- \_\_\_\_k. When an electrical current passes through an electrical resistance or other electrical load, work is done, and electrical energy is transformed into heat, light, or forms of mechanical work.
- \_\_\_\_l. The measure of work performed by electrical energy is the watt.

5. Complete statements concerning batteries by circling the word(s) or figure(s) that best complete(s) each statement.

- a. One of the main sources of (**stationary, portable**) electricity is the battery.
- b. Batteries convert (**thermal, chemical**) energy into electricity.
- c. Batteries are composed of a chemical solution called an electrolyte and two different kinds of metals called the (**plates, dividers**).
- d. The positive ions in an electrolyte collect on one of the battery (**plates, dividers**) and the negative ions in an electrolyte collect on the other battery (**plate, divider**).



## TEST

- e. A battery is made up of battery cells connected in (**a series, parallel**).
  - f. The most common battery used in automobiles is called a (**maintenance free, lead-acid**) battery.
  - g. Automobile batteries are made up of six lead-acid cells connected in series to give a battery voltage of (**12, 6**) volts.
  - h. Each of the lead-acid cells making up the battery produces approximately (**2, 3**) volts.
  - i. (**Lead-acid, Solar**) batteries used in automobiles can supply electrical energy to do work such as turn a starter motor or light head lamps.
  - j. As a battery supplies energy or power, the battery discharges, the chemical action that produces electricity decreases, and an internal resistance develops that (**limits, increases**) maximum current flow.
  - k. An automobile battery can also be recharged with a(n) (**alternator, power supply**).
6. Complete statements concerning alternators by circling the word(s) that best complete(s) each statement.
- a. When an electric current flows through a conductor, it establishes (**resistance, a magnetic field**) around the conductor.
  - b. Since a moving electric charge creates (**resistance, a magnetic field**), the key words are movement, electric charges (**magnetic field, resistance**), and if any two of the above are present, the third will occur.
  - c. *Moving a conductor (**into, across**) a magnetic field will create an electrical current* in the conductor that will flow through the complete electrical circuit.
  - d. The concept of (**inducing, conducting**) electricity is used to build electric generators and automobile alternators which are used to charge automotive batteries.
  - e. The alternator voltage is slightly (**less, greater**) than the battery voltage and forces a reversal of the chemical action within the battery, and reversal action recharges the battery.
7. Select true statements concerning Ohm's law by placing an "X" beside each statement that is true.

(NOTE: For a statement to be true, all parts of the statement must be true.)

- \_\_\_\_\_ a. Ohm's law expresses the relationship of voltage, current, and resistance in an electrical circuit.
- \_\_\_\_\_ b. Ohm's law states: The current flowing in an electrical circuit is directly proportional to the voltage, and inversely proportional to the circuit resistance.



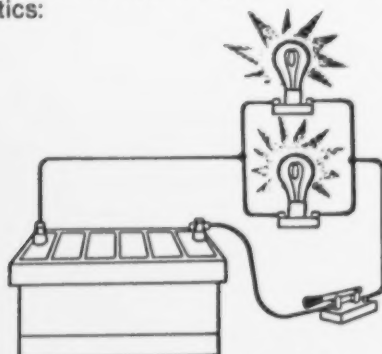
## TEST

- \_\_\_\_\_c. Ohm's law uses symbols to represent the three electrical quantities:
- 1) E is the symbol for voltage (pressure), and is measured in volts.
  - 2) I is the symbol for current (rate of flow), and is measured in amperes.
  - 3) R is the symbol for resistance (load), and is measured in ohms.
- \_\_\_\_\_d. When at least two electrical quantities are known, Ohm's law can be used to find the other unknown quantity, as expressed in mathematical formulas:
- 1)  $E = I \times R$  (amperage times resistance)
  - 2)  $I = E / R$  (voltage divided by resistance)
  - 3)  $R = E / I$  (voltage divided by amperage)
8. Solve problems concerning Kirchhoff's laws for voltage and current by answering the following questions.
- a. What is the sum of the voltage drops in a closed loop equal to?
- Answer: \_\_\_\_\_
- b. What is the sum of currents into any point in a circuit equal to?
- Answer: \_\_\_\_\_
9. Solve problems concerning theories of current flow by answering the following questions.
- a. What current flow theory is used in automotive and solid-state electronics applications?
- Answer: \_\_\_\_\_
- b. In terms of positive and negative, which way does the current flow if your answer to the previous question is correct?
- Answer: \_\_\_\_\_

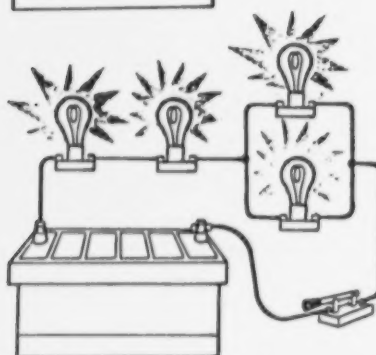
## TEST

10. Identify a series circuit by placing an "X" beside the series circuit depicted in the following schematics:

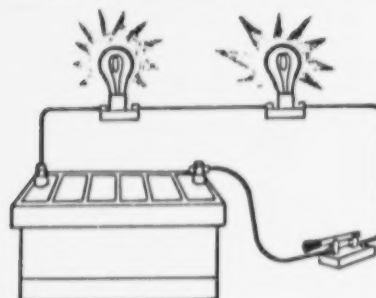
\_\_\_\_ a.



\_\_\_\_ b.

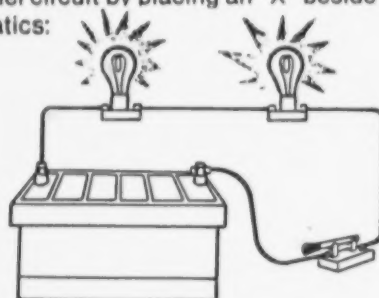


\_\_\_\_ c.



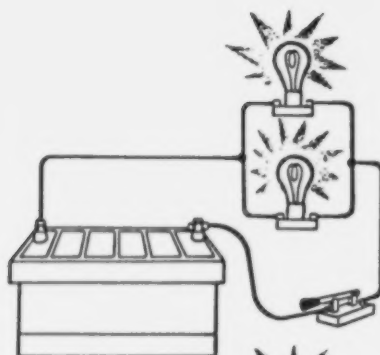
11. Identify a parallel circuit by placing an "X" beside the parallel circuit depicted in the following schematics:

\_\_\_\_ a.

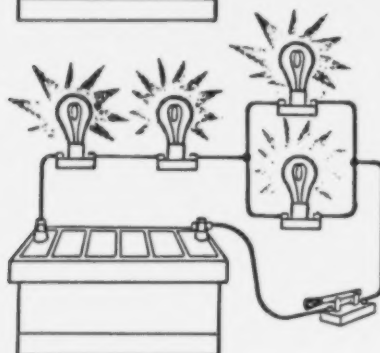


TEST

\_\_\_\_ b.

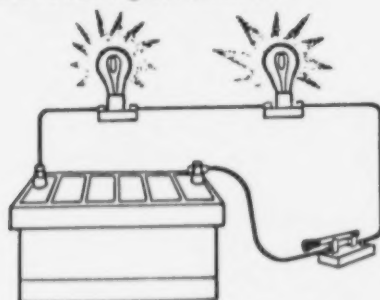


\_\_\_\_ c.

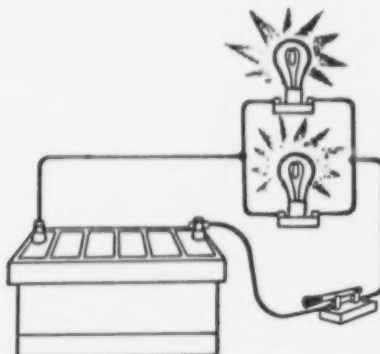


12. Identify a series-parallel circuit by placing an "X" beside the series-parallel circuit depicted in the following schematics:

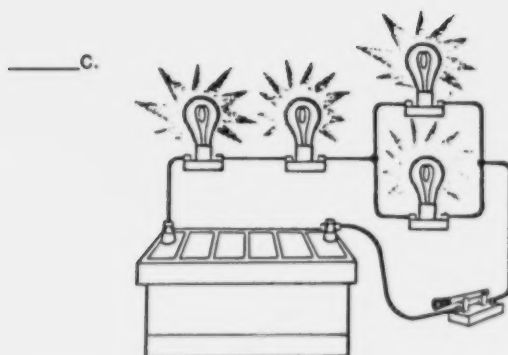
\_\_\_\_ a.



\_\_\_\_ b.



## TEST



13. Complete statements concerning voltage measurements by circling the word(s) that best complete(s) each statement.
- (**Voltage, Current**) measurements are made with a voltmeter.
  - Voltages are measured (**across, in series with**) resistors and sources such as batteries and power supplies.
  - Voltmeters have very (**high, low**) resistance in order not to disturb the circuit under test.
  - Since the voltmeter is across a resistor or source, it is in (**series, parallel**) with the resistor or source.
  - There are two common types of voltmeters, analog and (**digital, binary**).
  - Analog voltmeters indicate a voltage reading with a (**pointer on a scale, numerical readout**).
  - Digital voltmeters indicate the voltage reading as a digital (**code, display**) and have to be used in some applications.
14. Complete statements concerning current measurements by circling the word(s) that best complete(s) each statement.
- Current measurements are made with a(n) (**ammeter, voltmeter**).
  - Current measurements are made by placing the (**voltmeter, ammeter**) in series with the circuit being measured:
    - The circuit must be (**opened, closed**) and the meter placed into the circuit.
    - The circuit must flow through the (**ammeter, voltmeter**).
  - (**Ammeters, Voltmeters**) must have very (**high, low**) resistance; the presence of the (**ammeter, voltmeter**) should change the circuit under test as little as possible.
  - There are two kinds of ammeters, (**analog, resistive**) and digital.

## TEST

15. Complete statements concerning resistance measurements by circling the word(s) that best complete(s) each statement.
- a. Resistance measurements are made with an (**ohmmeter, ohmmeter or a trouble-light**).
  - b. Resistance (**must not, must**) be measured with an ohmmeter while power is applied to the circuit.
  - c. An ohmmeter contains (**its own, an outside**) voltage source, usually a low voltage battery.
  - d. Ohmmeters are available (**as both analog and digital instruments, only as analog instruments**).
16. Select true statements concerning multimeters by placing an "X" beside each statement that is true.
- \_\_\_\_ a. Since common circuit measurements are voltage, current, and resistance, these functions have been incorporated into a single instrument called a multimeter.
  - \_\_\_\_ b. To use a multimeter, the function switch is first turned to the quantity to be measured, voltage, current, or ohms.
  - \_\_\_\_ c. Once the function has been set, select the range of the quantity to be measured.
  - \_\_\_\_ d. Multimeters are available only as analog instruments.
  - \_\_\_\_ e. Analog multimeters are easier to read, and in high impedance applications, they do a better job than digital meters.
  - \_\_\_\_ f. Remember that a multimeter becomes a voltmeter, an ammeter, or an ohmmeter depending on the function switch setting.
  - \_\_\_\_ g. The multimeter is the most widely used basic circuit analysis and testing tool in electronics.
17. Select true statements concerning linear DC by placing an "X" beside each statement that is true.
- \_\_\_\_ a. Linear DC is a fluctuating value.
  - \_\_\_\_ b. Linear DC is only negative with respect to a reference point such as the automobile chassis.

## TEST

18. Select true statements concerning pulsating DC by placing an "X" beside each statement that is true.
- \_\_\_\_\_a. Pulsating DC changes value with time, but never crosses the zero reference.
  - \_\_\_\_\_b. Pulsating DC may be either positive or negative with respect to a reference point such as the automobile chassis.
  - \_\_\_\_\_c. A sophisticated instrument called a pulsar is used to measure pulsating DC.
19. Complete statements concerning conductors by circling the word(s) that best complete(s) each statement.
- a. Conductors are the wires or (**metals, ceramics**) that easily conduct electrical currents in circuits.
  - b. The most common electrical conductor is (**copper wire, silver**).
  - c. All conductors have some resistance based on length, diameter, and temperature:
    - 1) The longer the wire, the (**higher, lower**) the resistance.
    - 2) The (**larger, smaller**) in diameter the wire, the higher the resistance.
    - 3) The hotter the wire, the (**lower, higher**) the resistance.
  - d. The important characteristics of (**copper, aluminum**) conductors are summarized in a wire gage table.
20. Solve problems concerning insulators by answering the following questions.
- a. Insulating materials cover conductors to protect circuits, but what else do they protect?  
Answer: \_\_\_\_\_
  - b. What are some of the things that can happen when an insulator fails?  
Answer: \_\_\_\_\_

## TEST

21. Select true statements concerning connectors by placing an "X" beside each statement that is true.

(NOTE: For a statement to be true, all parts of the statement must be true.)

- \_\_\_\_a. Many electrical connectors are connected to the conductors of a circuit or cable by solder.
- \_\_\_\_b. Solder is a mixture of lead and zinc, a metal with a low melting temperature.
- \_\_\_\_c. Solder is used to make electrical connections between conductors, and also used to create a strong mechanical connection.
- \_\_\_\_d. To properly solder a connection:
  - 1) Clean the connection or joint with a resin paste or flux.
  - 2) Heat the joint with a soldering iron.
  - 3) Apply the solder so that it melts and forms a bright, smooth appearance at the joint.
  - 4) Tape the connection to insulate it from corrosion.
- \_\_\_\_e. Common errors in soldering are:
  - 1) Failure to properly clean the joint.
  - 2) Not heating the joint sufficiently, forming a cold solder joint that looks dull and rough.
  - 3) Using too much solder.
  - 4) Using improper flux.
- \_\_\_\_f. In automotive circuits, connections are often made with crimp connectors.
- \_\_\_\_g. Crimp connectors are special connectors that have a sleeve that the conductor is slipped into; the sleeve is crushed using a special tool to form a mechanically strong solderless connection.
- \_\_\_\_h. Crimp connections never fail.
- \_\_\_\_i. A newer and far superior technique is to use solder to form the electrical connection and to make the connection corrosion resistant by covering it with heat shrink.
- \_\_\_\_j. While the conductor is soldered to the connector, the crimp is made on the conductor's insulation.



## TEST

22. Complete statements concerning fuses by circling the word(s) that best complete(s) each statement.
- a. A (**low cost and effective, quick**) method of protecting circuits from excessive current flow is to fuse the circuit.
  - b. A fuse is a (**metal, ceramic**) link selected and shaped to allow continuous current flow up to some predetermined amperage.
  - c. When predetermined amperage is exceeded, the (**ceramic, metal**) link melts, and the fuse (**blows, stops conducting temporarily**).
  - d. When a fuse (**blows, stops**), it is calling attention to a circuit problem (**that should be corrected, that may require future attention**).
  - e. *Never* replace a fuse with one that has a higher amperage rating (**because circuit protection will be lost, unless you have to**).
  - f. Replacing a fuse with one with a higher rating may lead to expensive destruction of circuit components and/or (**electrical fires, loss of power to other circuits**).
  - g. Fusible links are used in (**lighting, power**) circuits, and like all other fuses, should be replaced with a fusible link of the same resistance.
23. Complete statements concerning circuit breakers by circling the word(s) that best complete(s) each statement.
- a. Circuit breakers are (**switches, circuit protectors**) that can usually be reset, and don't have to be replaced like fuses do.
  - b. Circuit breakers are usually of the thermal type; when they get too hot from excessive current flowing through them, the circuit they are protecting is (**opened, shorted to ground**).
  - c. Thermal circuit breakers are composed of a small resistor used as a (**relay, heating element**) and a bi-metal switch.
  - d. A bi-metal switch is composed of (**two, three**) different metals that expand at different rates as they are heated.
  - e. If a circuit breaker continues to trip, it's a sure sign that the (**circuit needs to be tested, circuit breaker is faulty**).



## TEST

24. Select true statements concerning inductors by placing an "X" beside each statement that is true.

(NOTE: For a statement to be true, all parts of the statement must be true.)

- \_\_\_\_a. A current flowing through a conductor produces a magnetic field around the conductor.
- \_\_\_\_b. The effects of this magnetic field may be strengthened by forming the conductor into a coil; the result is called an inductor.
- \_\_\_\_c. The inductor has limited uses in electrical and electronic circuits.
- \_\_\_\_d. An inductor may be wound to form an ignition coil to produce high voltage from a low voltage source:
  - 1) When the circuit closes, current flows through only part of the coil and a slowly expanding magnetic field is created around the entire coil or inductor.
  - 2) When the circuit opens, the magnetic field quickly collapses inducing a very high voltage in the total coil, and this high voltage is used to fire spark plugs.
  - 3) The magnetic field is strengthened by inserting a soft iron core into the center of the coil.

25. Select true statements concerning capacitors by placing an "X" beside each statement that is true.

- \_\_\_\_a. Capacitors are two plates of conducting material separated by an insulating material called an electrolyte.
- \_\_\_\_b. A capacitor may be charged—that is, the capacitor may have excessive negative charges on one plate and a deficiency of negative charges on the other plate.
- \_\_\_\_c. The electrical energy of a charged capacitor is stored in the electrolyte between the conducting plates.
- \_\_\_\_d. A capacitor may be charged or discharged through a resistor.
- \_\_\_\_e. The larger the capacitor value in capacitance, and the larger the resistance value in ohms, the longer it will take the capacitor to charge or discharge.
- \_\_\_\_f. When a capacitor is charged or discharged through a resistor, the circuit is often called a series circuit.

## TEST

- \_\_\_\_\_g. RC circuits are frequently used in timing applications, and to suppress voltage spikes from inductors.
- \_\_\_\_\_h. The unit of measure for capacitance is the ohm.
26. Complete statements concerning switches by circling the word(s) that best complete(s) each statement.
- a. The most basic mechanical switch is one that either closes or opens a circuit, and is called a **(single-pole, single-throw switch, one-way switch)**.
  - b. Switches come in all sorts of configurations and may have **(many, up to three)** poles or contacts.
  - c. **(Multi-throw, Dual-purpose)** switches offer circuit alternatives such as turning on high or low beam lights.
27. Solve problems concerning electromechanical relays by answering the following questions.
- a. Electromechanical relays allow a small amount of current to pass through a coil to accomplish what?  
Answer: \_\_\_\_\_
  - b. What is another name for a high-power relay?  
Answer: \_\_\_\_\_
28. Complete statements concerning schematic diagrams by inserting the word(s) that best complete(s) each statement.
- a. Schematic diagrams are drawings made up of \_\_\_\_\_ to represent circuit components.
  - b. Schematic diagrams are used to show much circuit information in \_\_\_\_\_ space.
  - c. With practice, schematic diagrams become easy to follow and the physical circuit easy to \_\_\_\_\_.
29. Complete statements concerning scientific notation by circling the word(s) that best complete(s) each statement.
- a. Scientific notation or powers of ten convey **(fractions, whole numbers)** or multiples of basic units of volts, amps, or ohms.
  - b. It is common practice to use names and **(symbols, numbers)** to represent commonly occurring powers of ten.

## TEST

- c. One reason for using powers of ten is that it simplifies **(using digital devices, computations)**.
  - d. In multiplication the powers of ten are **(added, multiplied)**.
  - e. In division the powers of ten are **(subtracted, divided)**.
30. Select true statements concerning troubleshooting an open circuit by placing an "X" beside each statement that is true.
- \_\_\_\_ a. An open circuit means that there is a short in the circuit, and there is an extra path for current to flow.
  - \_\_\_\_ b. In a series circuit, an open will stop all current flow, but in a parallel circuit, an open will affect half the branches.
  - \_\_\_\_ c. One method of finding an open is to use a jumper wire to bypass a suspected trouble spot; if the jumper wire makes the circuit operational, the open is in the part of the circuit that was jumped.
  - \_\_\_\_ d. A continuity check with an ohmmeter or a self-powered test light is another way to check for an open, but be sure the circuit has first been disconnected from its voltage source.
31. Select true statements concerning troubleshooting a short to ground by placing an "X" beside each statement that is true.
- \_\_\_\_ a. A short to ground interrupts the normal current path in a circuit, and stops current flow.
  - \_\_\_\_ b. Because a short to ground creates low resistance, a large current flow results, and it usually opens protection devices in the circuit, and blows a fuse, opens a fusible link, or cycles a circuit breaker on and off.
  - \_\_\_\_ c. In circuits that have no fuse, a short to ground is dangerous because it may burn wire, and even produce flames.
  - \_\_\_\_ d. A test light can be used to locate a short to ground by putting the test light where you think the short is.
  - \_\_\_\_ e. With the test light installed, disconnect circuit components in a logical order, and when the test light goes out, it indicates the trouble spot.
  - \_\_\_\_ f. A circuit breaker and a compass can also be used to locate a short to ground by removing the fuse, and connecting the circuit breaker to the first terminals.
  - \_\_\_\_ g. As the circuit heats and cools, the circuit breaker will open and close, and by moving the compass along the circuit, the point where there is no current flow can be isolated because the compass needle will stop deflecting.

## TEST

32. Select true statements concerning troubleshooting shorts into another circuit by placing an "X" beside each statement that is true.
- ☐ a. A short to another circuit is usually caused when insulation breaks off wires, causing two bare wires to touch.
  - ☐ b. A short into another circuit can also be caused by a damaged wiring harness.
  - ☐ c. A short into another circuit can actually create new circuits, and cause strange things to happen.
  - ☐ d. Shorts into the voltage of another circuit are always easy to find.
  - ☐ e. Look for bare wires that are touching, remove fuses to isolate the problem, and make voltage checks at logical points in the circuits.
  - ☐ f. A test light can be used to check for voltage along a circuit, but NEVER use a test light on circuits that contain solid-state components which could be damaged.
33. Select true statements concerning troubleshooting high-resistance problems by placing an "X" beside each statement that is true.
- ☐ a. High-resistance problems reduce current flow in a circuit, and can cause lamps to dim or flicker, or result in components that don't work at all.
  - ☐ b. High-resistance problems can be caused by damaged wires, but frequently will be the result of connectors that are corroded, dirty, or loose.
  - ☐ c. High-resistance problems are sometimes the most difficult to find, and test instruments are important in high-resistance troubleshooting.
  - ☐ d. High-resistance problems are frequently ground problems, and guidelines for troubleshooting more complex high-resistance problems are included in service manuals.

(NOTE: If the following activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

- 34. Calculate voltage using Ohm's law. (Assignment Sheet #1)
- 35. Calculate current flow in amperes using Ohm's law. (Assignment Sheet #2)
- 36. Calculate resistance using Ohm's law. (Assignment Sheet #3)

**TEST**

37. Demonstrate the ability to:
- a. Measure voltage drops in a series circuit. (Job Sheet #1)
  - b. Analyze current values in a series circuit. (Job Sheet #2)
  - c. Measure voltage, current, and resistance in a parallel circuit. (Job Sheet #3)
  - d. Troubleshoot series-parallel circuits. (Job Sheet #4)

## AUTOMOTIVE DC ELECTRONICS UNIT III

### ANSWERS TO TEST

1.   a.   5                   e.   13                   i.   1                   m.   2  
     b.   8                   f.   12                   j.   4  
     c.   10                  g.   7                   k.   6  
     d.   11                  h.   3                   l.   9
  
2.   a, b, c, d, e, f, j, k, l, m, n, q, r
  
3.   a.   By creating friction between two different substances  
     b.   Electrostatic discharge can damage or destroy sensitive electronic components
  
4.   b, c, e, g, h, i, j, k, l
  
5.   a.   Portable  
     b.   Chemical  
     c.   Plates  
     d.   Plates, plate  
     e.   A series  
     f.   Lead-acid  
     g.   12  
     h.   2  
     i.   Lead-acid  
     j.   Limits  
     k.   An alternator
  
6.   a.   A magnetic field  
     b.   A magnetic field, magnetic field  
     c.   Across  
     d.   Inducing  
     e.   Greater
  
7.   a, b, c, d
  
8.   a.   The applied voltage  
     b.   The sum of the current out of that point
  
9.   a.   The conventional theory  
     b.   From positive to negative

## ANSWERS TO TEST

10. c
11. b
12. c
13. a. Voltage  
b. Across  
c. High  
d. Parallel  
e. Digital  
f. Pointer on a scale  
g. Display
14. a. An ammeter  
b. Ammeter  
    1) Opened  
    2) Ammeter  
c. Ammeters, low, ammeter  
d. Analog
15. a. An ohmmeter  
b. Must not  
c. Its own  
d. As both analog and digital instruments
16. a, b, c, f, g
17. Neither statement is true
18. a, b
19. a. Metals  
b. Copper wire  
c. 1) Higher  
    2) Smaller  
    3) Higher  
d. Copper

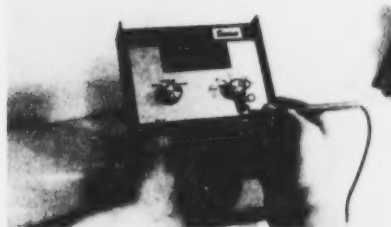
## ANSWERS TO TEST

20. a. Technicians who work on circuits  
b. A short circuit, excessive current flow, damage to circuit components, and perhaps a fire
21. a, d, e, f, g, i, j
22. a. Low cost and effective  
b. Metal  
c. Metal, blows  
d. Blows, that should be corrected  
e. Because circuit protection will be lost  
f. Electrical fires  
g. Power
23. a. Circuit protectors  
b. Opened  
c. Heating element  
d. Two  
e. Circuit needs to be tested
24. a, b, d
25. b, d, e, g
26. a. A single-pole, single-throw switch  
b. Many  
c. Multi-throw
27. a. To complete a high power circuit  
b. Solenoid
28. a. Symbols  
b. Limited  
c. Visualize
29. a. Fractions  
b. Symbols  
c. Computations  
d. Added  
e. Subtracted



**ANSWERS TO TEST**

- 30. c, d
- 31. b, c, e, f, g
- 32. a, b, c, e, f
- 33. a, b, c, d
- 34. Assignment Sheet #1 evaluated to the satisfaction of the instructor
- 35. Assignment Sheet #2 evaluated to the satisfaction of the instructor
- 36. Assignment Sheet #3 evaluated to the satisfaction of the instructor
- 37. Job sheets evaluated according to the criteria in the practical tests



## **SEMICONDUCTORS**

### **UNIT IV**

#### **UNIT OBJECTIVE**

After completion of this unit, the student should be able to discuss the structure and operations of diodes and bipolar transistors. The student should also be able to name types of field effect transistors and discuss their applications. The student should also be able to test diodes, and check a hall effect switch for distributor reference signals. These competencies will be evidenced by correctly performing the procedures outlined in the job sheets and by scoring a minimum of 85 percent on the unit test.

#### **SPECIFIC OBJECTIVES**

After completion of this unit, the student should be able to:

1. Match terms related to semiconductors with their correct definitions.
2. Select true statements concerning diode construction.
3. Complete statements concerning diode action.
4. Differentiate between symbols for other diode types.
5. Solve problems concerning bipolar transistor structure.
6. Complete statements concerning transistor operation.
7. Solve problems concerning transistor applications.
8. Complete statements concerning field effect transistors.
9. Select true statements concerning insulated gate FETs.
10. Select true statements concerning complementary metal oxide FETs.
11. Complete statements concerning integrated circuits.
12. Solve problems concerning silicon controlled rectifiers.
13. Complete statements concerning hall effect devices.
14. Identify rectifier circuits.

**OBJECTIVE SHEET**

15. Select true statements concerning guidelines for handling static sensitive devices.
16. Demonstrate the ability to:
  - a. Perform a static test of semiconductor diodes. (Job Sheet #1)
  - b. Check a hall effect switch for proper voltages. (Job Sheet #2)

## SEMICONDUCTORS UNIT IV

### SUGGESTED ACTIVITIES

- A. Provide students with objective sheet.
- B. Provide students with information and job sheets.
- C. Make transparencies.
- D. Discuss unit and specific objectives.
- E. Discuss information sheet.
- F. Discuss and demonstrate the procedures outlined in the job sheets.
- G. Have an alternator available to demonstrate to students how diodes are used in rectifier circuits.
- H. Give test.

### REFERENCES USED IN DEVELOPING THIS UNIT

- A. Harwick, Jim. *General Industrial Electronics*. Stillwater, OK: Oklahoma Curriculum and Instructional Materials Center, 1984.
- B. Willison, Neal and James Shelton. *Basic Electronics II*. Stillwater, OK: Mid-America Vocational Curriculum Consortium, 1981.
- C. Bignell, James and Robert Donovan. *Digital Electronics*. Albany, NY 12212: Delmar Publishers, Inc., 1985.
- D. *Fundamentals of Electronics and Semiconductors*. Benton Harbor, MI: Heath Company, 1985.

## SEMICONDUCTORS UNIT IV

### INFORMATION SHEET

#### I. Terms and definitions

- A. Base — Control section that varies conductivity of the transistor
- B. Channel— Narrow path within a field-effect transistor through which conduction of current is controlled
- C. Collector — Section of transistor in which majority current carriers are *collected* out of the device
- D. Depletion mode — Field-effect transistor operation in which a negative voltage on the gate repels electrons in the channel and reduces conduction
- E. Depletion region — Area within semiconductor material where charge carriers are neutralized
- F. Doping — Process of adding current-conducting impurities into crystal materials to make semiconductors
- G. Drain — Electrode of a field-effect transistor corresponding to the collector of a bipolar transistor
- H. Emitter — Most heavily doped section of transistor where majority current carriers travel inward, and *emitted* into the device
- I. Enhancement mode — Field-effect transistor operation in which a positive voltage on the gate attracts electrons into the channel and increases conduction
- J. Gate — Electrode of various semiconductor devices that provides control for operation
- K. Pinch-off voltage — Voltage from the gate to the source of field-effect transistors at which conduction of current ceases
- L. Saturation — When an increase in collector voltage no longer causes an increase in collector current; and with an increase in base current it no longer causes an increase in collector current
- M. Source — Electrode of a field-effect transistor corresponding to the emitter of a bipolar transistor
- N. Substrate — Base material of an integrated-circuit chip upon which the circuitry is formed.

(NOTE: Some integrated circuits have a pin connection to the substrate, which drains static charges, or to references to a voltage bias.)

## INFORMATION SHEET

- O. Transistor — Solid-state semiconductor device usually having three terminals; varies conductivity according to voltage and current inputs

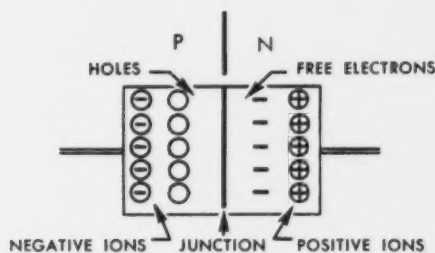
### II. Diode construction

- A. A diode is formed by joining positive and negative semiconductor materials so that they form a PN junction.
- B. The P(+) materials is usually silicon doped with boron, and the N(-) materials is usually silicon doped with phosphorous.

(NOTE: Germanium is also used as a diode base, but silicon is used more often in automotive applications.)

- C. Doping creates an excess number of free electrons in N material, and holes in P material.
- D. Although the P and N materials attract each other at the PN junction, the negative ions on the P side of the junction, and the positive ions on the N side of the junction pull back on the free electrons and holes to keep them from crossing the junction until the diode has power applied to it. (Figure 1)

FIGURE 1



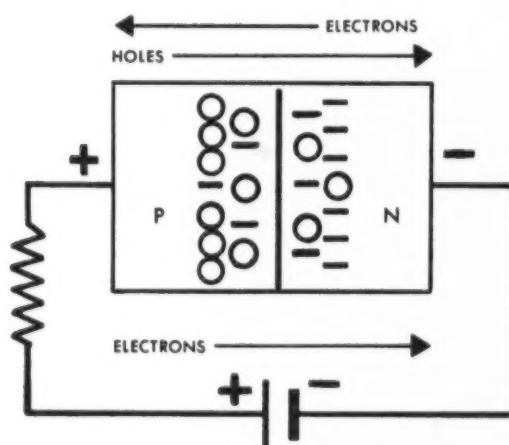
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### III. Diode action

- A. When negative battery voltage is applied to N material in a diode, a positive voltage is applied to P material in the diode, electrons will move across the PN junction to create current flow.
- B. When a diode has negative voltage applied to the N material, and positive voltage applied to the P material, current flows across a diode, and the diode has a "forward bias." (Figure 2)

## INFORMATION SHEET

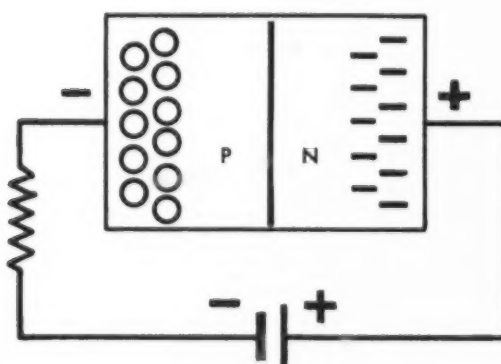
FIGURE 2



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- C. When negative battery voltage is applied to P material, and positive voltage is applied to N material, no current will flow, and the diode has a "reverse bias." (Figure 3)

FIGURE 3



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## INFORMATION SHEET

- D. The arrowhead in the diode schematic symbol always points TOWARD the N material. (Figure 4)

FIGURE 4



- E. The areas close to each side of the PN junction are called the "depletion region" when action causes a barrier potential to be developed, and the barrier potential has to be exceeded before the diode will conduct current. (Transparency 1)
- F. A silicon diode barrier is typically 0.7 volts.
- G. When reverse bias current is too high and too long, it can cause excessive heat and damage the diode.

### IV. Other diode types

- A. Zener diodes are specifically designed to conduct current in the reverse direction. (Figure 5)

FIGURE 5



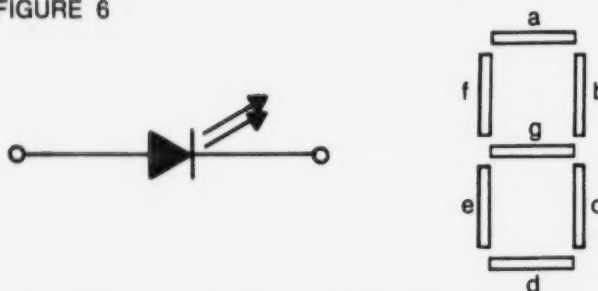
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- B. The zener threshold for reverse bias flow is called the "avalanche voltage," and voltage below that point will not cause current flow, but current above the avalanche point will allow current to flow without damaging the diode.
- C. The zener diode structure makes it an effective device in control circuits such as regulators where it also is used to establish accurate reference voltages.
- D. An LED (light emitting diode) emits light when current passes through it, and is used in displays or indicators that need to be visible. (Figure 6)



## INFORMATION SHEET

FIGURE 6

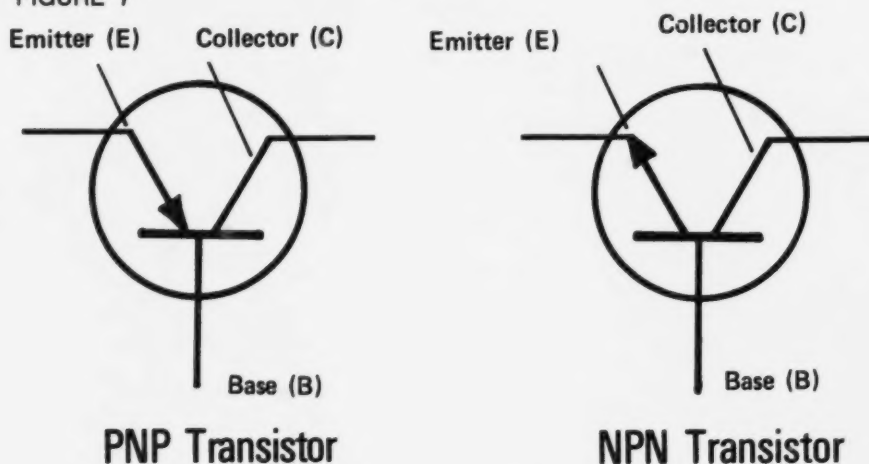


- E. Many vehicles use an LED in a VSS (vehicle speed sensor):
1. The LED shines onto a rotating disc that alternately does and does not reflect light from the LED.
  2. A photo transistor is used to register reflected light, and the digital (on/off) signal produced is used by the CPU to monitor vehicle speed.

## V. Bipolar transistor structure

- A. Transistors are usually made by adding a second section of P material to the same PN junction used in diodes, or adding a second section of N material to a PN junction.
- B. Transistors are used to control current flow, and of the two configurations, PNP and NPN, the PNP transistors are used more often in automotive applications.
- C. PNP and NPN transistors have different schematic symbols, but in both symbols, the arrow points toward the N-type material. (Figure 7)

FIGURE 7



## INFORMATION SHEET

- D. In a PNP transistor, the P on the left is the emitter, the N in the center is the base, and the P on the right is the collector.
- E. In an NPN transistor, the N materials are on the left and right with the P material in the center.
- F. In transistor schematics, the base is always the center material.

### VI. Transistor operation

- A. With a PNP transistor, if the circuit of the base is energized and the collector is open, then current will flow from the emitter through the base.  
  
(NOTE: Just as with a diode, transistor current flow is actually "hole" movement.)
- B. If the PNP collector circuit is closed, then the majority of current flow will pass through the emitter to the collector because of the negative potential in the collector P-type material.
- C. If the PNP base circuit is opened, then current flow stops whether or not the collector circuit is closed, because the base no longer accepts holes from the emitter.
- D. When the PNP base is open, the negative battery potential in the collector attracts the holes away from the base collector junction, assisting in the resistance to current flow.
- E. The really useful aspect of transistors is that by using a relatively small base current, a much larger current can be controlled.
- F. Because of their characteristics, transistors are used in amplifier circuits, ignition modules, and regulators.
- G. When transistors are used as switches, they are normally OFF and turned ON.

### VII. Transistor applications

- A. Because of their capacity to amplify input signals, transistors are much more versatile than single diodes, and can be manufactured in many sizes and for several applications.
- B. Transistors with three leads may be connected with different circuit configurations:
  - 1. Common base
  - 2. Common emitter
  - 3. Common collector

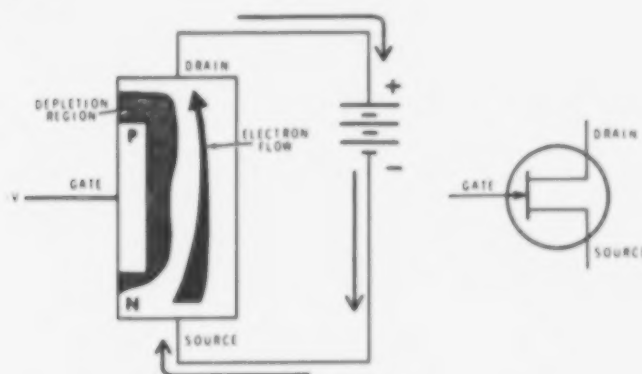
## INFORMATION SHEET

- C. Transistors may be used with zener diodes as voltage regulators in configurations where the zener diode acts as a voltage reference for the transistor.
- D. With the zener diode providing voltage reference, the voltage across the base-emitter junction of the transistor may increase or decrease slightly, but the circuit will still be able to maintain a near constant output voltage.
- E. Another type of voltage regulator that uses transistors and a zener diode is the series regulator.
- F. In a series regulator, the one transistor actually compares the differences between two voltages in order to adjust the resistance of another transistor and maintain a near constant voltage across the load. (Transparency 3)

### VIII. Field effect transistors

- A. The FET (field effect transistor) is a solid state device with three terminals called the source, drain, and gate, which roughly correspond to the emitter, collector, and base in a junction transistor.
- B. The FET differs from a normal junction transistor in that the amount of voltage (instead of current) applied to the gate determines the current flow from the source to drain.
- C. Since no current flows into the gate, the impedance is very high (from  $10^6$  to  $10^{14}\Omega$ ).
- D. In an FET, the source and drain are both attached to the N-type section which is known as the channel. (Figure 8)

FIGURE 8

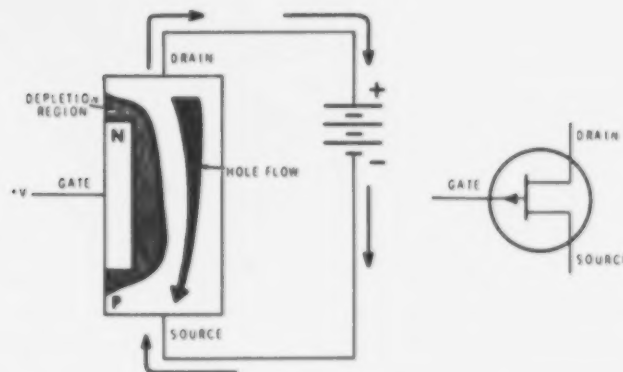


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## INFORMATION SHEET

- E. Reverse bias voltage is applied to the gate to control current flow through the channel.
- F. If the gate voltage is high enough, the depletion region will completely cover the channel and stop current flow; this is known as "pinch off."
- G. A P-channel FET is just the reverse voltage operation of an N-channel FET, and the arrow on the symbol always points to the N-material. (Figure 9)

FIGURE 9

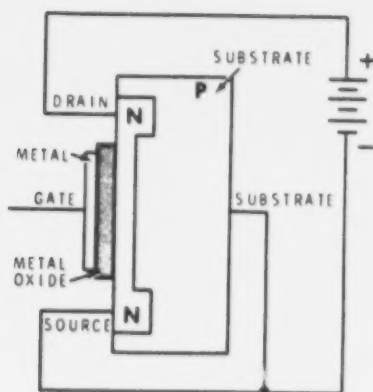


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- H. FETs are usually ON and turned OFF.
- IX. **Insulated gate FETs**
- A. An IGET uses a metal gate that is electrically insulated from the channel by a thin layer of oxide. (Figure 10)
  - B. Because of the insulating layer of oxide, these FETs are also called metal oxide semiconductor FETs or MOSFETs. (Figure 10)

## INFORMATION SHEET

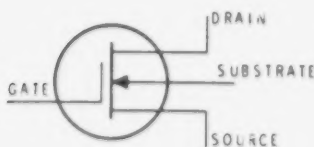
FIGURE 10



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- C. MOSFETs may be made as either P-channel or N-channel devices, and operate in modes directly related to positive or negative input voltages.
- D. Like a junction FET, reverse bias applied to the MOSFET gate will diminish current flow through the channel, and the MOSFET is said to be in the "depletion" mode. (Figure 11)

FIGURE 11

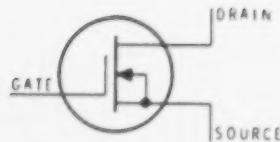


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- E. Unlike a junction FET, forward bias applied to the MOSFET gate will enhance current flow through the channel, and the MOSFET is said to be in the "enhancement" mode. (Figure 12)

## INFORMATION SHEET

FIGURE 12



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- F. MOSFETs are easy to manufacture, and consume less power than other types of FETs, but they are easily damaged by static electricity, and must be shipped and handled with care.

### X. Complementary metal oxide FETs

- A. When a P-channel MOSFET and an N-channel MOSFET are configured to work together, the device is called a CMOS (complementary metal oxide semiconductor).
- B. Because the P and N materials in a CMOS react differently to an input signal, these devices are often used to make digital logic gates.
- C. CMOSs are used in many ICs (integrated circuits), and like MOSFETs, they must be shipped and handled with care.

### XI. Integrated circuits (Transparency 2)

- A. Integrated circuits, or ICs, are complete circuits embedded in semiconductor material rather than being a circuit composed of individual diodes, transistors, and resistors.
- B. IC technology has revolutionized the computer world, and IC circuits have found many other applications in devices such as voltage regulators and amplifiers.
- C. Like some other FETs, ICs are subject to damage by static electricity, and must be shipped and handled with care. (Figure 13)

## INFORMATION SHEET

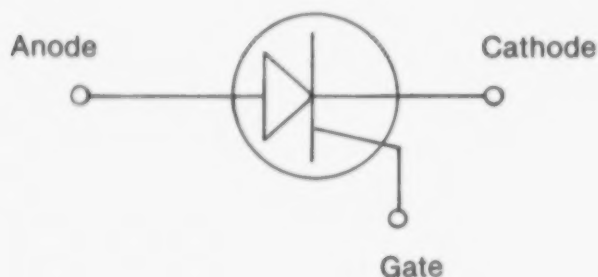
FIGURE 13



### XII. Silicon controlled rectifiers (Transparency 3)

- A. An SCR (silicon controlled rectifier) is a semiconductor that will not allow current to flow in either direction until it is triggered by a positive pulse on its gate.
- B. In an SCR, current flows from the anode to the cathode, and unlike a transistor switch, the SCR will continue to pass current even after the triggering signal is removed.
- C. After it is triggered, the only way to shut off an SCR is to remove the source voltage from the device.
- D. The SCR has a unique construction and a special symbol. (Figure 14)

FIGURE 14



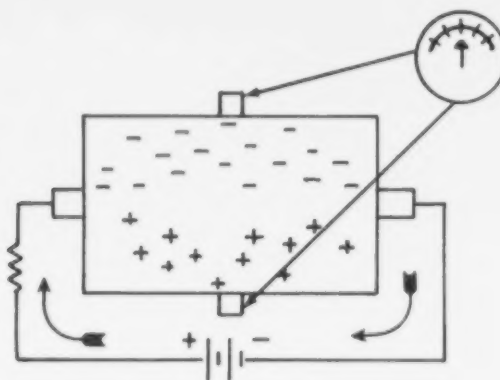
### XIII. Hall effect devices

- A. A hall effect device is a semiconductor that reacts to the presence or absence of a magnetic field.
- B. Hall effect devices are made of thin wafers of semiconductor material.

## INFORMATION SHEET

- C. When a magnetic field is present, current flowing through a hall effect device is displaced to one side, causing voltage to be developed across the wafer. (Figure 15)

FIGURE 15



- D. Hall effect switches are used in automotive ignition primary circuits to generate a digital signal which is more accurate in the control of spark timing.
- E. With a hall effect switch in the distributor, the ignition module no longer needs a signal converter to generate the engine RPM reference signal to the computer.
- F. Since A/D converters are relatively slow, the use of hall effect switches makes the ignition system more responsive to slight changes.
- G. Because of their rapid response characteristics, hall effect switches are also used in anti-skid brake systems.

### XIV. Rectifier circuits

- A. Because alternators are more compact than generators, and can supply a higher current at low engine speed, alternators are used in most modern automobiles.
- B. Because an alternator produces AC power, that power has to be rectified to DC power to operate automotive circuits.
- C. To rectify or change the AC power to DC power, diodes are used in rectifier circuits.
- D. When only one diode is used in a rectifier circuit, it becomes what is called a "half-wave" rectifier because it allows DC to flow through the load only during one-half of each AC input. (Figure 16)



## INFORMATION SHEET

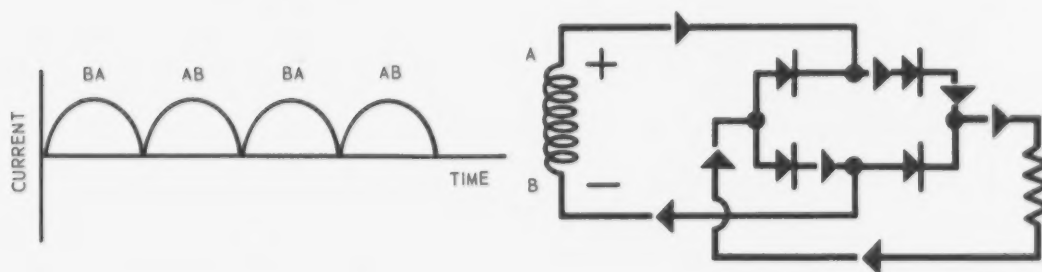
FIGURE 16



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- E. Although an alternator with only one diode would have limited output, the peak output voltage of a half-wave rectifier is twice the peak voltage of a full-wave rectifier.
- F. To increase output, a full-wave rectifier may use four diodes to convert AC voltage to pulsating DC voltage, and provides a more continuous current than a half-wave rectifier, but because the current varies from a maximum to a zero value, the full-wave rectifier does not produce the most output that can be obtained from an alternator. (Figure 17)

FIGURE 17

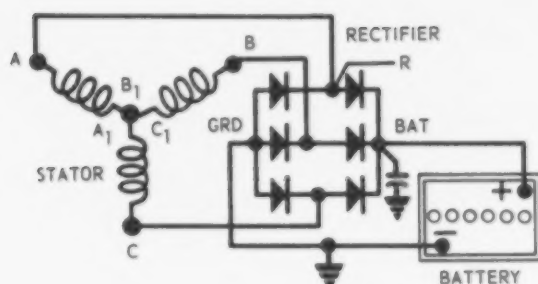


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- G. To produce higher output and smoother voltage and current, six diodes are used with a three-phase stator to form what is called a "three-phase full-wave bridge rectifier" that is used with both "Y" and Delta stator connections. (Figure 18)

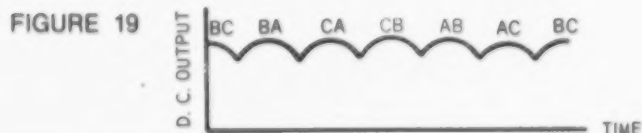
## INFORMATION SHEET

FIGURE 18



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- H. The advantage of the full-wave bridge amplifier is that it gives full wave rectification like the full-wave rectifier, but it also provides the peak output voltage of a half-wave rectifier, and gives a smooth, almost non-varying DC voltage. (Figure 19)



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- I. To protect an alternator from damage, an isolation diode is placed between the battery and the alternator to block current flow back to the alternator when the alternator is not operating.

### XV. Guidelines for handling static sensitive devices

- A. Many everyday activities generate electrostatic voltage which can evidence itself in the form of electrostatic discharge.

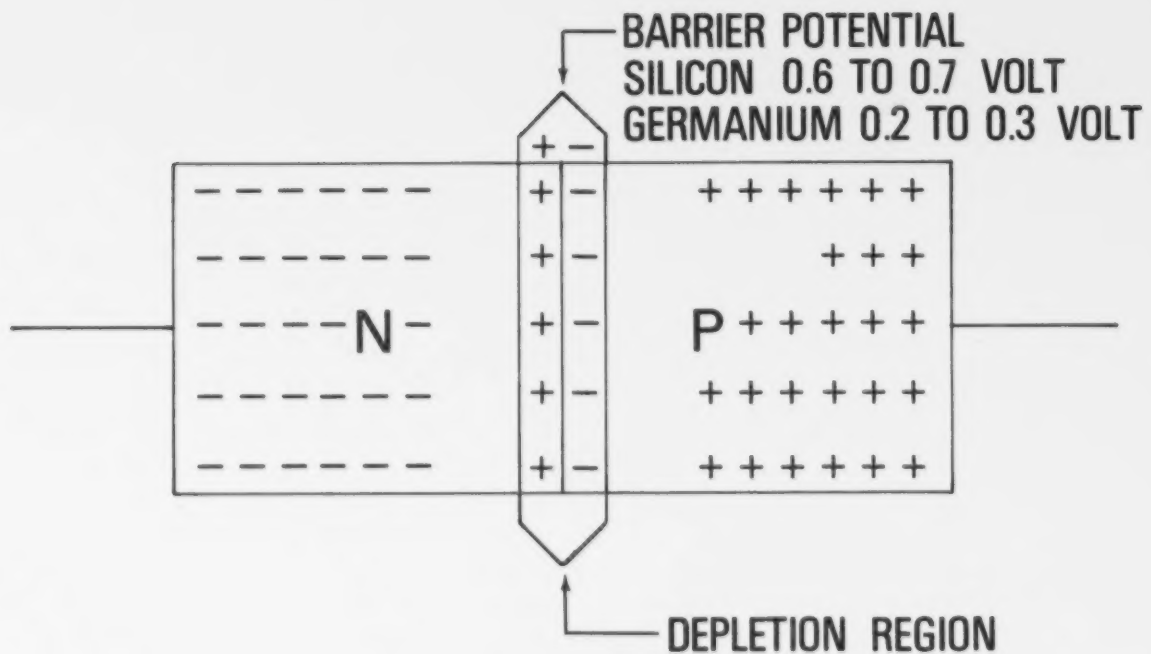
Example: It's easy to build up to 6,000 volts while moving across a car seat.

- B. Grounding devices such as antistatic mats and grounded wrist bands are recommended safety devices for service technicians who work with static sensitive semiconductors.

## INFORMATION SHEET

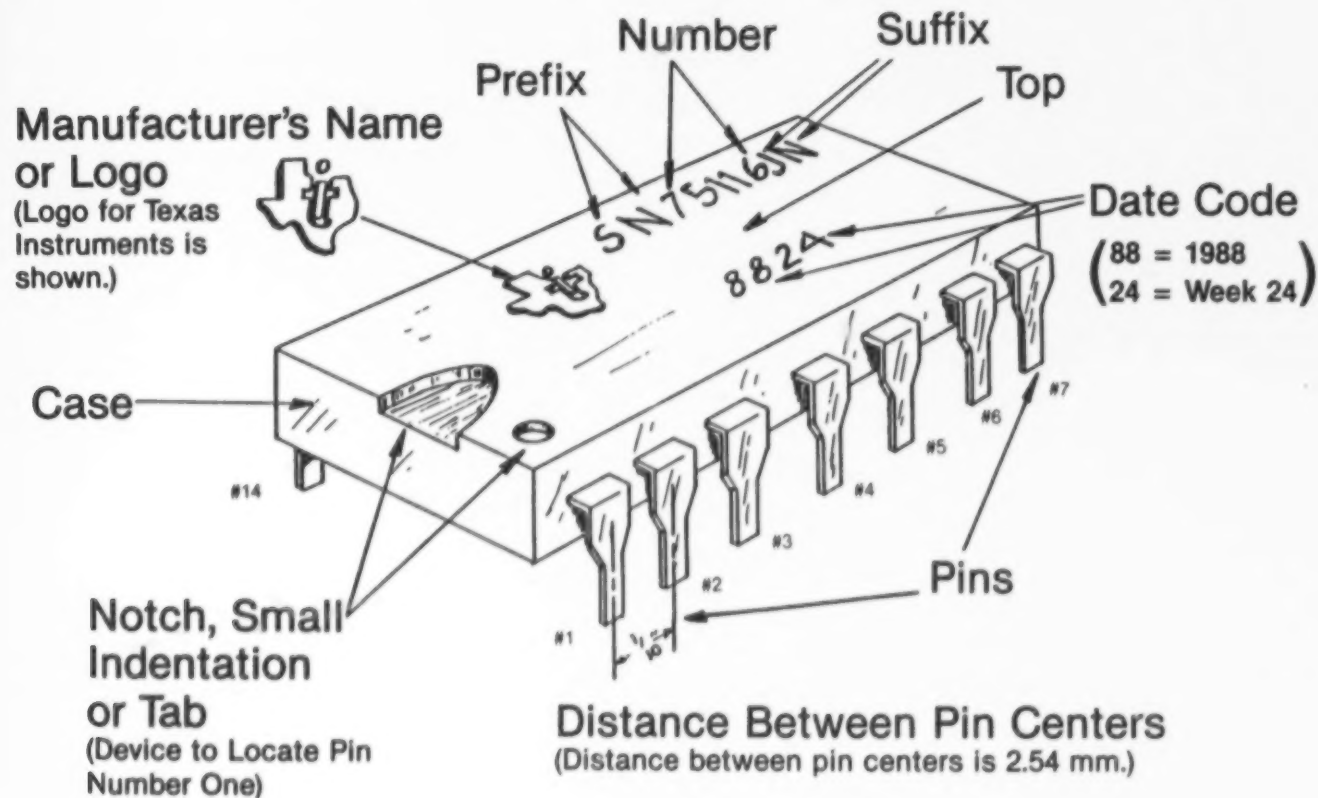
- C. Soldering around semiconductors should be done with a soldering iron with a grounded tip, and modern soldering irons do have grounded tips.
- D. IC's are shipped in antistatic packages, and the packaging should be left in place until the IC is put into use, and then the IC should be handled in a static free environment.
- E. Heating dries out inside air in winter months, and such working environments need humidification to help control electrostatic buildup.

# P-N Junction

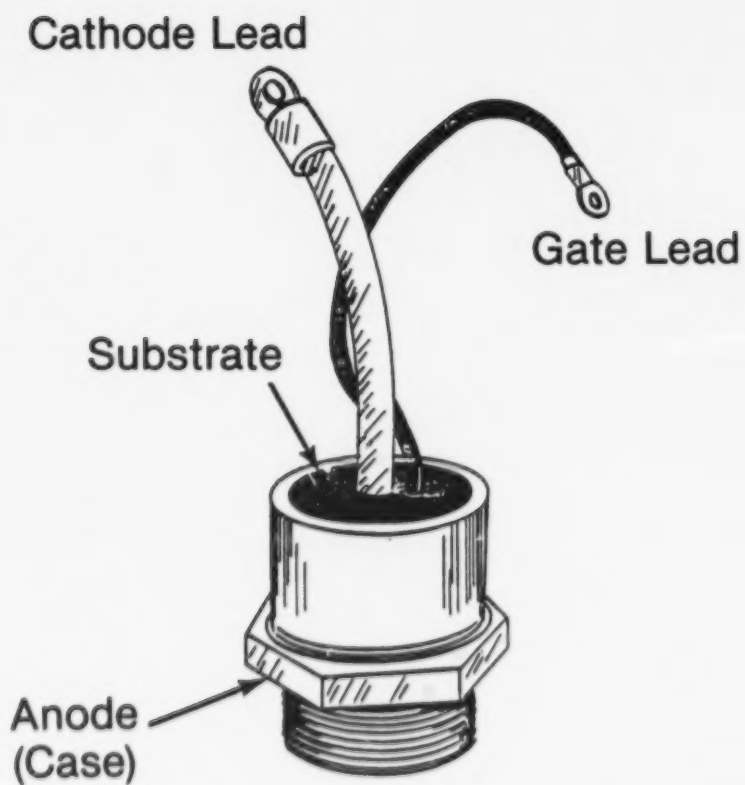


P-N JUNCTION  
Showing Barrier Potential  
And  
Depletion Region

# Typical Integrated Circuit



# Silicon Controlled Rectifier



## SEMICONDUCTORS UNIT IV

### JOB SHEET #1 — PERFORM A STATIC TEST OF SEMICONDUCTOR DIODES

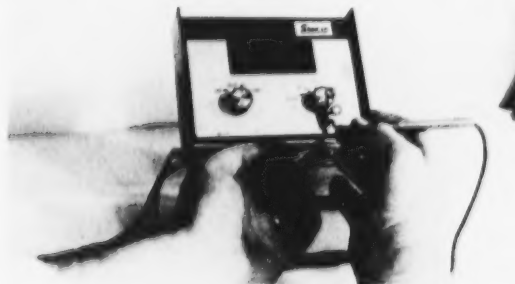
#### A. Tools and equipment

1. DVOM (with minimum impedance of 20 megohms)
2. Four different diodes (more at instructor's option)
3. Alternator rectifier bridge (optional)
4. Appropriate service manual (if rectifier bridge is used)
5. Pencil
6. Safety glasses

#### B. Procedure

1. Take the diodes (or alternator rectifier) to a clean area on a work bench.
2. Put on safety glasses.
3. Set the DVOM to read ohms on the diode scale or the  $R \times 100$  scale to avoid possible damage to the diodes.
4. Select the first diode and connect the positive lead of the DVOM to the anode, and the negative lead to the cathode of the diode. (Figure 1)

FIGURE 1



5. Read and record your meter measurements under FORWARD BIAS on the Diode Data Table that accompanies this job sheet.

## JOB SHEET #1

6. Reverse the DVOM leads, positive lead to cathode, negative lead to anode, and record your meter measurements under REVERSE BIAS on the Diode Data Table that accompanies this job sheet. (Figure 2)

FIGURE 2



7. Repeat the static test procedure for each of the selected diodes, and make appropriate entries on your data table.
8. Evaluate each diode as good or bad by looking for a forward/reverse bias ratio of about 100 to 1.
9. Complete all data table entries.  
☐ Have your instructor check your work.
10. Clean area, and return tools and equipment to proper storage.



## JOB SHEET #1

Name \_\_\_\_\_

Date \_\_\_\_\_

Diode Data Table

| DIODE          | FORWARD<br>BIAS | REVERSE<br>BIAS | GOOD OR<br>BAD |
|----------------|-----------------|-----------------|----------------|
| D <sub>1</sub> |                 |                 |                |
| D <sub>2</sub> |                 |                 |                |
| D <sub>3</sub> |                 |                 |                |
| D <sub>4</sub> |                 |                 |                |

## SEMICONDUCTORS UNIT IV

### JOB SHEET #2 — CHECK A HALL EFFECT SWITCH FOR PROPER VOLTAGES

#### A. Tools and equipment

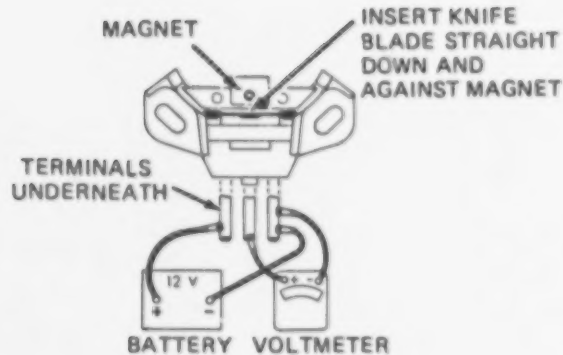
1. Vehicle with hall effect ignition
2. Appropriate service manual
3. Basic hand tools
4. DVOM
5. Fender covers
6. Pencil
7. Pocket knife
8. Safety glasses

#### B. Procedure

1. Put on safety glasses.
2. Bring vehicle into shop area, and install fender covers.
3. Install exhaust removal equipment.
4. Open the hood of the vehicle and secure it.
5. Follow service manual instructions, and prepare distributor so that the hall effect switch is accessible.
6. Refer to Figure 1 as you complete this procedure. (Figure 1)

## JOB SHEET #2

FIGURE 1



Courtesy Chevrolet Division, General Motors Corporation

7. Connect the battery and the DVOM to the hall effect switch terminals indicated in Figure 1.
8. Record the reading on the DVOM \_\_\_\_\_ .
  - a. If the reading is less than 0.5 volts, the switch is okay.
  - b. If the reading is above 0.5 volts, the switch is defective.
9. Insert the blade of a knife straight down and against the magnet in the hall effect switch.
10. Record the reading on the DVOM \_\_\_\_\_ .
  - a. If the reading is within 0.5 volts of the battery voltage (above or below), the switch is okay.
  - b. If the reading is outside the 0.5 volt limit, the switch is defective.
11. Replace the hall effect switch if it is defective.
 

☐ Have your instructor check your work.
12. Replace the distributor cover, and start the vehicle to verify proper operation.
13. Secure vehicle, and return tools and materials to proper storage.

## SEMICONDUCTORS UNIT IV

### PRACTICAL TEST #1 JOB SHEET #1 — PERFORM A STATIC TEST ON SEMICONDUCTOR DIODES

Student's name \_\_\_\_\_

Date \_\_\_\_\_

Evaluator's name \_\_\_\_\_

Attempt no. \_\_\_\_\_

Student instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

#### PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

| The student:                                           | YES                         | NO                       |
|--------------------------------------------------------|-----------------------------|--------------------------|
| 1. Wore safety glasses.                                | 1. <input type="checkbox"/> | <input type="checkbox"/> |
| 2. Properly set DVOM.                                  | 2. <input type="checkbox"/> | <input type="checkbox"/> |
| 3. Made and recorded forward bias reading.             | 3. <input type="checkbox"/> | <input type="checkbox"/> |
| 4. Made and recorded reverse bias reading.             | 4. <input type="checkbox"/> | <input type="checkbox"/> |
| 5. Evaluated diodes properly.                          | 5. <input type="checkbox"/> | <input type="checkbox"/> |
| 6. Returned equipment and materials to proper storage. | 6. <input type="checkbox"/> | <input type="checkbox"/> |

Evaluator's comments: \_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

## JOB SHEET #1 PRACTICAL TEST

### PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another test procedure must be submitted for evaluation.)

Criteria:

|                        |                    |                          |                          |               |
|------------------------|--------------------|--------------------------|--------------------------|---------------|
| Tool and Equipment Use | Excellent<br>4     | Good<br>3                | Fair<br>2                | Poor<br>1     |
| Test Procedure         | Well Done<br>4     | Acceptably Done<br>3     | Poorly Done<br>2         | Improper<br>1 |
| Diode Data Table       | Complete<br>4      | Acceptable<br>3          | Incomplete<br>2          | Improper<br>1 |
| Safety                 | Well Observed<br>4 | Acceptably Observed<br>3 | Improperly Observed<br>2 | Careless<br>1 |

EVALUATOR'S COMMENTS: \_\_\_\_\_

#### PERFORMANCE EVALUATION KEY

- 4 — Skilled — Can perform job with no additional training.
- 3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
- 2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
- 1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

**SEMICONDUCTORS  
UNIT IV****PRACTICAL TEST #2  
JOB SHEET #2 — CHECK A HALL EFFECT SWITCH FOR  
DISTRIBUTOR REFERENCE SIGNALS**

Student's name \_\_\_\_\_

Date \_\_\_\_\_

Evaluator's name \_\_\_\_\_

Attempt no. \_\_\_\_\_

Student instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

**PROCESS EVALUATION**

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

| The student:                                           | YES                         | NO                       |
|--------------------------------------------------------|-----------------------------|--------------------------|
| 1. Wore safety glasses.                                | 1. <input type="checkbox"/> | <input type="checkbox"/> |
| 2. Made distributor wiring check properly.             | 2. <input type="checkbox"/> | <input type="checkbox"/> |
| 3. Properly recorded DVOM measurements.                | 3. <input type="checkbox"/> | <input type="checkbox"/> |
| 4. Made CPU terminal check properly.                   | 4. <input type="checkbox"/> | <input type="checkbox"/> |
| 5. Properly recorded DVOM measurements.                | 5. <input type="checkbox"/> | <input type="checkbox"/> |
| 6. Verified on/off hall effect operation.              | 6. <input type="checkbox"/> | <input type="checkbox"/> |
| 7. Returned equipment and materials to proper storage. | 7. <input type="checkbox"/> | <input type="checkbox"/> |

Evaluator's comments: \_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

## JOB SHEET #2 PRACTICAL TEST

### PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another test procedure must be submitted for evaluation.)

Criteria:

|                          |                    |                          |                          |               |
|--------------------------|--------------------|--------------------------|--------------------------|---------------|
| Tool and Equipment Use   | Excellent<br>4     | Good<br>3                | Fair<br>2                | Poor<br>1     |
| Test Procedure           | Well Done<br>4     | Acceptably Done<br>3     | Poorly Done<br>2         | Improper<br>1 |
| Hall Effect Verification | Accomplished<br>4  | Acceptable<br>3          | Incomplete<br>2          | Improper<br>1 |
| Safety                   | Well Observed<br>4 | Acceptably Observed<br>3 | Improperly Observed<br>2 | Careless<br>1 |

EVALUATOR'S COMMENTS: \_\_\_\_\_

#### PERFORMANCE EVALUATION KEY

- 4 — Skilled — Can perform job with no additional training.
- 3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
- 2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
- 1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

# SEMICONDUCTORS

## UNIT IV

### TEST

NAME \_\_\_\_\_

SCORE \_\_\_\_\_

1. Match terms related to semiconductors with their correct definitions.

- |         |                                                                                                                                        |                       |
|---------|----------------------------------------------------------------------------------------------------------------------------------------|-----------------------|
| _____a. | Control section that varies conductivity of the transistor                                                                             | 1. Drain              |
| _____b. | Narrow path within a field-effect transistor through which conduction of current is controlled                                         | 2. Emitter            |
| _____c. | Section of transistor in which majority current carriers are <i>collected</i> out of the device                                        | 3. Doping             |
| _____d. | Field-effect transistor operation in which a negative voltage on the gate repels electrons in the channel and reduces conduction       | 4. Transistor         |
| _____e. | Area within semiconductor material where charge carriers are neutralized                                                               | 5. Substrate          |
| _____f. | Process of adding current-conducting impurities into crystal materials to make semiconductors                                          | 6. Depletion region   |
| _____g. | Electrode of a field-effect transistor corresponding to the collector of a bipolar transistor                                          | 7. Source             |
| _____h. | Most heavily doped section of transistor where majority current carriers travel inward, and <i>emitted</i> into the device             | 8. Base               |
| _____i. | Field-effect transistor operation in which a positive voltage on the gate attracts electrons into the channel and increases conduction | 9. Depletion mode     |
| _____j. | Electrode of various semiconductor devices that provides control for operation                                                         | 10. Saturation        |
| _____k. | Voltage from the gate to the source of field-effect transistors at which conduction of current ceases                                  | 11. Channel           |
|         |                                                                                                                                        | 12. Pinch-off voltage |
|         |                                                                                                                                        | 13. Collector         |
|         |                                                                                                                                        | 14. Gate              |
|         |                                                                                                                                        | 15. Enhancement mode  |



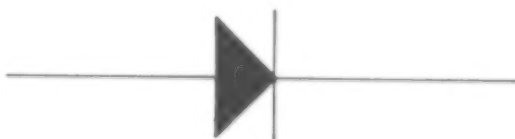
## TEST

- \_\_\_\_l. When an increase in collector voltage no longer causes an increase in collector current, and with an increase in base current it no longer causes an increase in collector current
  - \_\_\_\_m. Electrode of a field-effect transistor corresponding to the emitter of a bipolar transistor
  - \_\_\_\_n. Base material of an integrated-circuit chip upon which the circuitry is formed
  - \_\_\_\_o. Solid state semiconductor device usually having three terminals; varies conductivity according to voltage and current inputs
2. Select true statements concerning diode construction by placing an "X" beside each statement that is true.
- \_\_\_\_a. A diode is formed by joining positive and negative semiconductor materials so that they form a PN junction.
  - \_\_\_\_b. The P(+) material is usually silicon doped with boron, and the N(-) material is usually silicon doped with phosphorous.
  - \_\_\_\_c. Doping creates an excess number of holes in N material, and free-electrons in P material.
  - \_\_\_\_d. Although the P and N materials attract each other at the PN junction, the negative ions on the P side of the junction, and the positive ions on the N side of the junction pull back on the free electrons and holes to keep them from crossing the junction until the diode has power applied to it.
3. Complete statements concerning diode action by circling the word(s) that best complete(s) each statement.
- a. When negative battery voltage is applied to N material in a diode, a positive voltage is applied to P material in the diode, electrons will move across the PN junction to create (**current flow, voltage**).
  - b. When a diode has negative voltage applied to the N material, and positive voltage applied to the P material, current flows across a diode, and the diode has a ("**forward bias**", "**reverse bias**").
  - c. When negative battery voltage is applied to P material, and positive voltage is applied to N material, no current will flow, and the diode has a ("**reverse bias**", "**forward bias**").

## TEST

- d. The arrowhead in the diode schematic symbol always points TOWARD the (N, P) material.
  - e. The areas close to each side of the PN junction are called the "depletion region" where action causes a barrier potential to be developed, and the barrier potential has to be (**exceeded, equalled**) before the diode will conduct current.
  - f. A silicon diode barrier is typically (**0.7 volts, 1.5 volts**).
  - g. When reverse bias current is too high and too long, it can cause excessive (**heat, bias**) and damage the diode.
4. Differentiate between symbols for other diode types by placing an "X" beside the symbol for a zener diode.

\_\_\_\_ a.



\_\_\_\_ b.



5. Solve problems concerning bipolar transistor structure by answering the following questions.
- a. Which type of bipolar transistor is used more often in automotive applications, PNP or NPN?  
Answer: \_\_\_\_\_
  - b. In a bipolar transistor schematic symbol, where does the arrow point?  
Answer: \_\_\_\_\_
  - c. In transistor schematics, where is the base?  
Answer: \_\_\_\_\_

## TEST

6. Complete statements concerning transistor operation by circling the word(s) that best complete(s) each statement.
- a. With a PNP transistor, if the circuit of the base is energized and the collector is open, then current will flow from the emitter through the **(base, collector)**.
  - b. If the PNP collector circuit is closed, then the majority of current flow will pass through the emitter to the collector because of the **(negative, positive)** potential in the collector P-type material.
  - c. If the PNP base circuit is opened, then current flow stops whether or not the collector circuit is closed, because the base no longer accepts **(holes, ions)** from the emitter.
  - d. When the PNP base is open, the **(positive, negative)** battery potential in the collector attracts the holes away from the base collector junction, assisting in the resistance to current flow.
  - e. The really useful aspect of transistors is that by using a relatively **(small, large)** base current, a much **(larger, smaller)** current can be controlled.
  - f. Because of their characteristics, transistors are used in amplifier circuits, ignition modules, and **(regulators, clutches)**.
  - g. When transistors are used as switches, they are normally **(OFF, ON)** and turned **(ON, OFF)**.
7. Solve problems concerning transistor applications by answering the following questions.
- a. What is the advantage of using a zener diode as a voltage reference in a regulator?  
Answer: \_\_\_\_\_  
\_\_\_\_\_
  - b. What other type of voltage regulator uses transistors and a zener diode?  
Answer: \_\_\_\_\_  
\_\_\_\_\_
8. Complete statements concerning field effect transistors by circling the word(s) that best complete(s) each statement.
- a. The FET is a **(solid state, digital)** device with three terminals called the source, drain, and gate, which roughly correspond to the emitter, collector, and base in a junction transmitter.

## TEST

- b. The FET (**differs from, is the same as**) a normal junction transistor in that the amount of voltage applied to the gate determines the current flow from the source to drain.
  - c. Since no current flows into the gate, the impedance is very (**high, low**).
  - d. In an FET, the source and drain are both attached to the N-type section which is known as the (**channel, gate**).
  - e. Reverse bias voltage is applied to the gate to control current flow through the (**channel, source**).
  - f. If the gate voltage is high enough, the depletion region will completely cover the channel and stop current flow; this is known as ("**pinch off, override**").
  - g. A P-channel FET is just the reverse voltage operation of an N-channel FET, and the arrow on the symbol always points to the (**N-material, P-material**).
  - h. FETs are usually (**OFF, ON**) and turned (**OFF, ON**).
9. Select true statements concerning insulated gate FETs by placing an "X" beside each statement that is true.
- \_\_\_\_ a. An IGET uses a metal gate that is electrically insulated from the channel by a thin layer of oxide.
  - \_\_\_\_ b. Because of the insulating layer of oxide, these FETs are also called metal oxide semiconductor FETs or MOSFETs.
  - \_\_\_\_ c. MOSFETs may be made as either P-channel or N-channel devices, and operate in modes directly related to positive or negative input voltages.
  - \_\_\_\_ d. Like a junction FET, reverse bias applied to the MOSFET gate will diminish current flow through the channel, and the MOSFET is said to be in the "enhancement" mode.
  - \_\_\_\_ e. Unlike a junction FET, forward bias applied to the MOSFET gate will enhance current flow through the channel, and the MOSFET is said to be in the "depletion" mode.
  - \_\_\_\_ f. MOSFETs are easy to manufacture, and consume less power than other types of FETs, but they are easily damaged by static electricity, and must be shipped and handled with care.
10. Select true statements concerning complementary metal oxide FETs by placing an "X" beside each statement that is true.
- \_\_\_\_ a. When a P-channel MOSFET and an N-channel MOSFET are configured to work together, the device is called a CMOS.

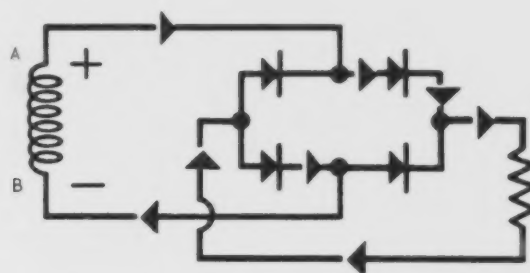
## TEST

- \_\_\_\_\_b. Because the P and N materials in a CMOS react differently to an input signal, these devices are often used to make digital logic gates.
- \_\_\_\_\_c. CMOSs are used in many ICs, and like MOSFETs, they must be shipped and handled with care.
11. Complete statements concerning integrated circuits by circling the word(s) that best complete(s) each statement.
- a. Integrated circuits, or ICs, are complete (**circuits, switches**) embedded in semiconductor material rather than being a circuit composed of individual diodes, transistors, and resistors.
  - b. IC technology has revolutionized the computer world, and IC circuits have found (**many other, a few**) applications in devices such as voltage regulators and amplifiers.
  - c. Like some other FETs, ICs are subject to damage by (**heat, static electricity**), and must be shipped and handled with care.
12. Solve problems concerning silicon controlled rectifiers by answering the following questions.
- a. An SCR will not allow current to flow in either direction until what happens?  
Answer: \_\_\_\_\_  
\_\_\_\_\_
  - b. What is the only way to shut off an SCR?  
Answer: \_\_\_\_\_
13. Complete statements concerning hall effect devices by circling the word(s) that best complete(s) each statement.
- a. A hall effect device is a semiconductor that reacts to the presence or absence of a (**magnetic field, current**).
  - b. Hall effect devices are made of thin (**wires, wafers**) of semiconductor material.
  - c. When a magnetic field is present, current flowing through a hall effect device is displaced to one side, causing voltage to be developed across the (**wire, wafer**).
  - d. Hall effect switches are used in automotive ignition primary circuits to generate a (**digital, analog**) signal which is more accurate in the control of spark timing.
  - e. With a hall effect switch in the distributor, the ignition module no longer needs a (**signal converter, rectifier**) to generate the engine RPM reference signal to the computer.

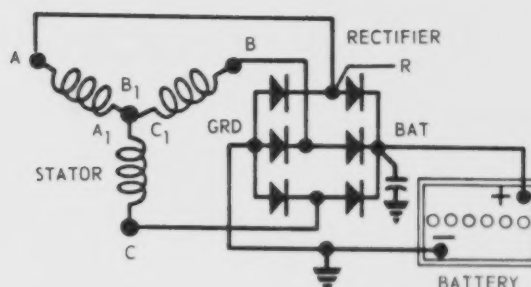
## TEST

- f. Since A/D converters are relatively slow, the use of hall effect switches makes the ignition system more responsive to (**rapid, slight**) changes.
- g. Because of their rapid response characteristics, hall effect switches are also used in (**anti-skid brake systems, climate control**).
14. Identify rectifier circuits by indicating which of the following is a full-wave rectifier, and a full-wave bridge rectifier.

\_\_\_\_ a.



\_\_\_\_ b.



15. Select true statements concerning guidelines for handling static sensitive devices by placing an "X" beside each statement that is true.
- \_\_\_\_ a. Many everyday activities generate electrostatic voltage which can evidence itself in the form of electrostatic discharge.
- \_\_\_\_ b. Grounding devices such as antistatic mats and grounded wrist bands are recommended safety devices for service technicians who work with static sensitive semiconductors.
- \_\_\_\_ c. Soldering around semiconductors should be done with a pencil-type soldering iron with or without a grounded tip.

**TEST**

- \_\_\_\_\_d. IC's are shipped in antistatic packages, and the packaging should be left in place until the IC is put into use, and then the IC should be handled in a static free environment.
- \_\_\_\_\_e. Heating dries out inside air in winter months, and such working environments need humidification to help control electrostatic buildup.

(NOTE: If the following activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

- 16. Demonstrate the ability to:
  - a. Perform a static test of semiconductor diodes. (Job Sheet #1)
  - b. Check a hall effect switch for distributor reference signals. (Job Sheet #2)

# **SEMICONDUCTORS UNIT IV**

## **ANSWERS TO TEST**

- |                                           |                                        |                                        |
|-------------------------------------------|----------------------------------------|----------------------------------------|
| 1. a. 8<br>b. 11<br>c. 13<br>d. 9<br>e. 6 | f. 3<br>g. 1<br>h. 2<br>i. 15<br>j. 14 | k. 12<br>l. 10<br>m. 7<br>n. 5<br>o. 4 |
|-------------------------------------------|----------------------------------------|----------------------------------------|
2. a, b, d
3. a. Current flow  
     b. Forward bias  
     c. Reverse bias  
     d. N  
     e. Exceeded  
     f. 0.7 volts  
     g. Head
4. b
5. a. PNP  
     b. Toward the N-type material  
     c. It is always the center material
6. a. Base  
     b. Negative  
     c. Holes  
     d. Negative  
     e. Small, larger  
     f. Regulators  
     g. OFF, ON
7. a. The circuit will be able to maintain a near constant output voltage  
     b. A series regulator
8. a. Solid state  
     b. Differs from  
     c. High  
     d. Channel



## ANSWERS TO TEST

- e. Channel
  - f. Pinch-off
  - g. N-material
  - h. ON, OFF
9. a, b, c, f
10. a, b, c
11. a. Circuits  
b. Many other  
c. Static electricity
12. a. Until it is triggered by a positive pulse on its gate  
b. Remove the source voltage from the device
13. a. A magnetic field  
b. Wafers  
c. Wafer  
d. Digital  
e. Signal converter  
f. Slight  
g. Anti-skid brake systems
14. a. Full-wave rectifier  
b. Full-wave bridge rectifier
15. a, b, d, e
16. Job sheets evaluated according to criteria in the practical tests.



## DIGITAL ELECTRONICS

### UNIT V

#### UNIT OBJECTIVE

After completion of this unit, the student should be able to discuss the basics of digital electronics, solve problems concerning logic gates and truth tables, and identify logic gates. The student should also be able to construct and test basic logic gates, and verify "Or Gate" operation in a cooling fan circuit. These competencies will be evidenced by correctly completing the procedures outlined in the assignment and job sheets, and by scoring a minimum of 85 percent on the unit test.

#### SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms related to digital electronics with their correct definitions.
2. Complete statements concerning digital overview.
3. Select true statements concerning binary digits.
4. Solve problems concerning logic gates and truth tables.
5. Identify an AND gate.
6. Identify an OR gate.
7. Identify a NOT gate.
8. Identify other basic logic gates.
9. Complete statements concerning D/A converters.
10. Complete statements concerning A/D converters.
11. Select true statements concerning multiplexing and demultiplexing.
12. Complete statements concerning fiber optics.
13. Complete truth tables for common logic devices. (Assignment Sheet #1)

**OBJECTIVE SHEET**

14. Demonstrate the ability to:
- a. Construct and test an "AND" gate circuit. (Job Sheet #1)
  - b. Construct and test an "OR" gate circuit. (Job Sheet #2)
  - c. Construct and test a "NAND" gate circuit. (Job Sheet #3)
  - d. Construct and test a "NOR" gate circuit. (Job Sheet #4)
  - e. Construct and test an "EXCLUSIVE-OR" gate circuit. (Job Sheet #5)
  - f. Verify "OR" gate operation in a cooling fan circuit. (Job Sheet #6)

## DIGITAL ELECTRONICS UNIT V

### SUGGESTED ACTIVITIES

- A. Provide students with objective sheet.
- B. Provide students with information sheet.
- C. Make transparencies.
- D. Discuss unit and specific objectives.
- E. Discuss information sheet.
- F. Discuss and demonstrate the procedures outlined in the job sheets.
- G. Use schematics from service manuals to demonstrate how logic gates are used in modern automotive applications.
- H. Invite a service manager from a local or area service center to talk to the class about troubleshooting digital devices.
- I. Give test.

### REFERENCES USED IN DEVELOPING THIS UNIT

- A. Cave and Terrell. *Digital Technology with Microprocessors*. Reston, VA: Reston Publishing Co., Inc., 1981.
- B. Floyd, Thomas L. *Digital Fundamentals*, Second Edition. Columbus, OH: Charles E. Merrill Co., 1982.
- C. Malvino, Albert P. *Digital Computer Electronics*, Second Edition. New York: McGraw-Hill Book Co., 1983.
- D. Rutkowski, George B. and Olesky, Jerome E. *Fundamentals of Digital Electronics*. Englewood Cliffs, NJ: Prentice-Hall, Inc., 1985.

## DIGITAL ELECTRONICS UNIT V

### INFORMATION SHEET

#### I. Terms and definitions

- A. Binary number system — Number system which has digits zero (0) and one (1) only
- B. Bit — A single binary digit, 0 or 1
- C. Digital circuit — A circuit that acts like a switch, either on or off
- D. Logic high — High voltage (usually five volts or more) representing binary 1
- E. Logic low — Low voltage (usually 0 or near 0) representing binary 0
- F. Truth table — Summarizes the various combinations of input and corresponding output signals for logic gates
- G. Word — A group of bits representing a complete piece of digital information

#### II. Digital overview

- A. There was a day when analog devices made up the world of electronics and instrumentation.
- B. Analog devices use continuous voltages or currents to represent naturally occurring physical changes of temperature, pressure, air speed, or a liquid level. (Figure 1)

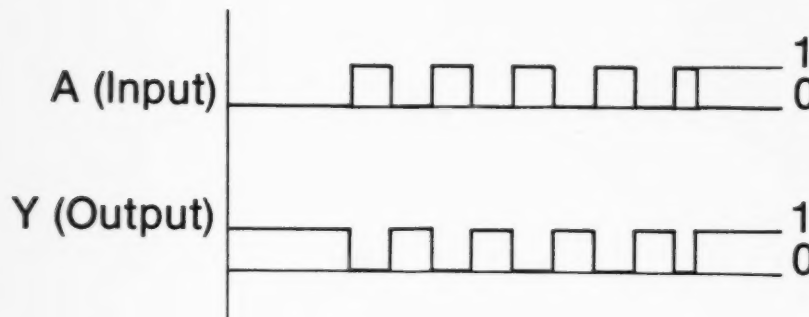
FIGURE 1



## INFORMATION SHEET

- C. In modern electronics and instrumentation, digital devices are being used more and more to measure and control many of the things formerly done by analog devices.
- D. Digital devices differ from analog devices in that digital voltages or currents are periodic, not continuous.
- E. Digital periodic voltage signals are at one of two allowed voltages for a short time, and these individual voltage level elements are called BITS.
- F. The two most common digital voltage levels are +5 volts and zero volts (TTL level) which can be used in a series of BITS to make up what is called a data word. (Figure 2)

FIGURE 2



- G. Data words can be transmitted from digital sensors to digital display devices to provide technicians with information vital for monitoring and evaluating operations of a single function or a system.

### III. Binary digits

- A. The individual BITS that make up a data word take their name from the two words Binary and digit.
- B. Since binary means two, a binary digit has only two numbers in it, and those numbers are 1 and 0.
- C. In digital circuits, +5 volts is often used to represent a binary 1, and 0 volts is used to represent a binary 0.

## INFORMATION SHEET

- D. Because a binary digit is either 1 or 0, binary circuits can be used to control opposing conditions such as a switch that is ON or OFF, a valve that is OPEN or CLOSED, a liquid that is HOT or COLD, and other opposite conditions.
- E. Binary bits are represented in a base 2 numbering system that permits bits to be used for measuring numerical values or quantities.
- F. The base 2 numbering system is similar to the base 10 or decimal numbering system which we use every day. (Transparency 1)
- G. Because of the nature of the base 2 numbering system, digital bits can be used to represent numerical quantities, and also for digital control.
- H. When the bit values of 1 and 0 are used for digital control, the bit value of 1 or 0 is called a logic state.

### IV. Logic gates and truth tables

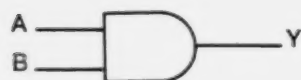
- A. Digital control circuits are made up of IC (integrated circuit) sub-circuits that are called logic gates.
- B. There are three basic logic gates that can be connected together to perform complex logic control jobs, and these gates are:
  - 1. The AND gate.
  - 2. The OR gate.
  - 3. The NOT gate.
- C. It is important to understand the operation of the three basic gates in order to understand how they can be manipulated in automotive logic networks.
- D. Logic gates have symbols which identify them and truth tables which show their functions.

## INFORMATION SHEET

### V. The AND gate (Transparency 2)

- A. The AND gate has a distinctive symbol, and uses the dot or multiplication sign to express the AND function. (Figure 3)

FIGURE 3



$$AB = Y$$

| A | B | Y |
|---|---|---|
| 0 | 0 | 0 |
| 0 | 1 | 0 |
| 1 | 0 | 0 |
| 1 | 1 | 1 |

- B. The AND gate function is defined by a truth table which contains absolutely every combination of input conditions, and the output state for each combination.
- C. Regardless of the number of inputs, in an AND gate the output will be true or 1 only when all the inputs are true or 1.
- D. A typical application of an AND gate is many automotive ignition systems where the car will not start unless the car is in park AND the key is turned to the start position.

### VI. The OR gate (Transparency 3)

- A. The OR gate has a distinctive symbol, and uses the plus or addition sign to denote the OR function. (Figure 4)

FIGURE 4



$$A + B = Y$$

| A | B | Y |
|---|---|---|
| 0 | 0 | 0 |
| 0 | 1 | 1 |
| 1 | 0 | 1 |
| 1 | 1 | 1 |

- B. The OR gate function is defined by a truth table which shows that the OR gate output is true or 1 when any of the inputs are true or 1.
- C. Each time an input is added to an OR gate, the number of entries in the truth table will double (Figure 4 is for a two-input OR gate).



## INFORMATION SHEET

- D. Regardless of the number of inputs, OR gate output will be true only if one or more than one of the inputs is true.
- E. A typical application of an OR gate is in most automobile convenience lighting where the dome light of the car will come on if any door is opened OR if the dome light switch is turned on.

### VII. The NOT gate (Transparency 4)

- A. The NOT gate has a distinctive symbol, and uses a bar over a variable to indicate the NOT function (Figure 5)

FIGURE 5



$$\bar{A} = Y$$

| A | Y |
|---|---|
| 0 | 1 |
| 1 | 0 |

- B. Since a NOT gate has only one input, the truth table for a NOT gate is simple.
- C. The bar over a NOT gate variable is read NOT, and this means that if the input is true, the NOT gate output would be false.

### VIII. Other basic logic gates

- A. In addition to the AND, OR, and NOT gates, other gates in common use are:
  1. The NAND gate. (Transparency 5)
  2. The NOR gate. (Transparency 6)
  3. The EXCLUSIVE-OR gate. (Transparency 7)
  4. The EXCLUSIVE-NOR gate. (Transparency 8)

## INFORMATION SHEET

- B. The NAND gate behaves like an AND gate followed by a NOT gate, and the NAND gate has a symbol like an AND gate except it has an inverting balloon on the output side. (Figure 6)

FIGURE 6

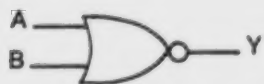


$$\overline{AB} = Y$$

| A | B | Y |
|---|---|---|
| 0 | 0 | 1 |
| 0 | 1 | 1 |
| 1 | 0 | 1 |
| 1 | 1 | 0 |

- C. As the NAND gate truth table shows, the output of a NAND gate is false or 0 when all inputs are true or 1.
- D. The NOR gate has a symbol like an OR gate, but it has an inverting balloon on the output. (Figure 7)

FIGURE 7



$$\overline{A + B} = Y$$

| A | B | Y |
|---|---|---|
| 0 | 0 | 1 |
| 0 | 1 | 0 |
| 1 | 0 | 0 |
| 1 | 1 | 0 |

- E. The NOR gate truth table shows that NOR gate output is true or 1 when all inputs are false or 0.
- F. The EXCLUSIVE-OR, XOR, gate has a symbol similar to the OR gate except that it has two tails and a circled plus sign to denote the XOR function. (Figure 8)

FIGURE 8



$$\overline{A}B + A\overline{B} = Y$$

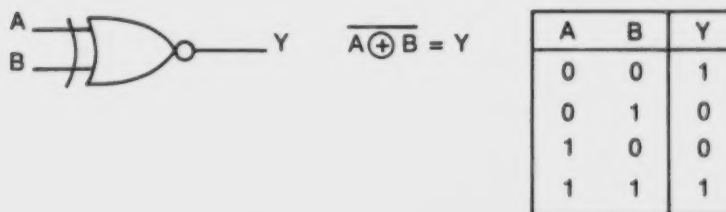
$$A \oplus B = Y$$

| A | B | Y |
|---|---|---|
| 0 | 0 | 0 |
| 0 | 1 | 1 |
| 1 | 0 | 1 |
| 1 | 1 | 0 |

## INFORMATION SHEET

- G. The XOR truth table shows that an XOR gate has only two inputs, and that the output will be true or 1 ONLY when the inputs are NOT the same.
- H. The EXCLUSIVE-NOR, XNOR, gate has a symbol like the XOR gate, but with an inverting balloon on the output. (Figure 9)

FIGURE 9



- I. The XNOR truth table shows that the XNOR gate has only two inputs, and that the output will be true or 1 only when the inputs are the SAME.

### IX. A/D converters (Transparency 9)

- A. Most automotive sensors generate an analog signal.
- B. Before a compute can handle analog information, the analog data must be converted to usable digital/binary information.
- C. Most automotive computers work with an 8-bit register that has a binary capacity of 256 maximum representations.
- D. An A/D converter receives an analog signal, converts it to a binary value, and then stores it in a #2 register where the computer compares it against a look-up table to determine the digital value.
- E. An A/D converter uses a series of "Exclusive Or" logic gates to do the comparisons, and when a perfect match is found, it yields a binary "O" in a #1 register.

### X. D/A converters

- A. Many automotive devices work on an analog signal, so to send digital information from the computer to an analog device requires a digital to analog conversion.
- B. D/A converters convert a binary number into a corresponding analog voltage level that is proportional to a binary input number.
- C. The most common D/A converters use 8-bit inputs, and the output voltage varies from 0 to 5 volts.

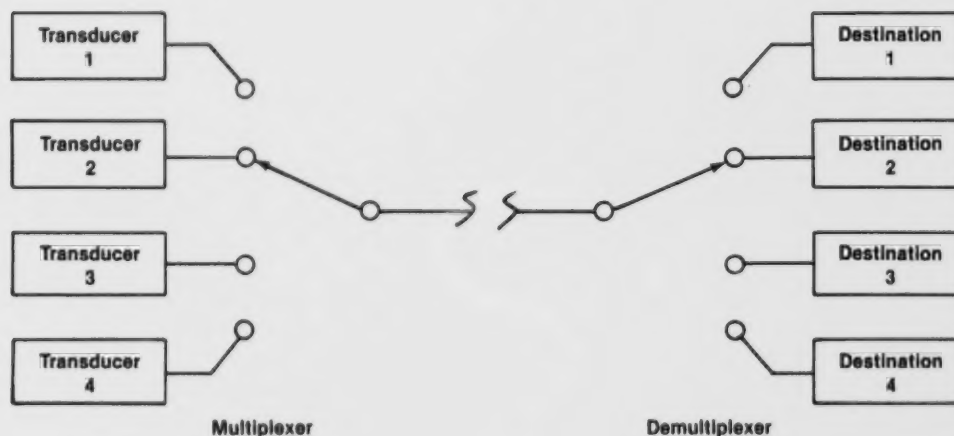
## INFORMATION SHEET

- D. A simple D/A converter uses a parallel input interface, and two operational amplifiers.
- E. The analog output is a stair-step voltage with the sampling rate as the determining factor for the value jumps between the steps.

### XI. Multiplexing and demultiplexing

- A. In cases where several transducers are sending signals to a central processing unit, wiring would be complex and too much weight would be added to a system if each transducer had its own conductor.
- B. To save weight and wiring complexity, multiplexers and demultiplexers allow several transducers to time-share a single transmission line.
- C. One approach to multiplexing/demultiplexing is to use rotary switches so synchronized that the switch wipers are in the correct positions at all times. (Figure 10)

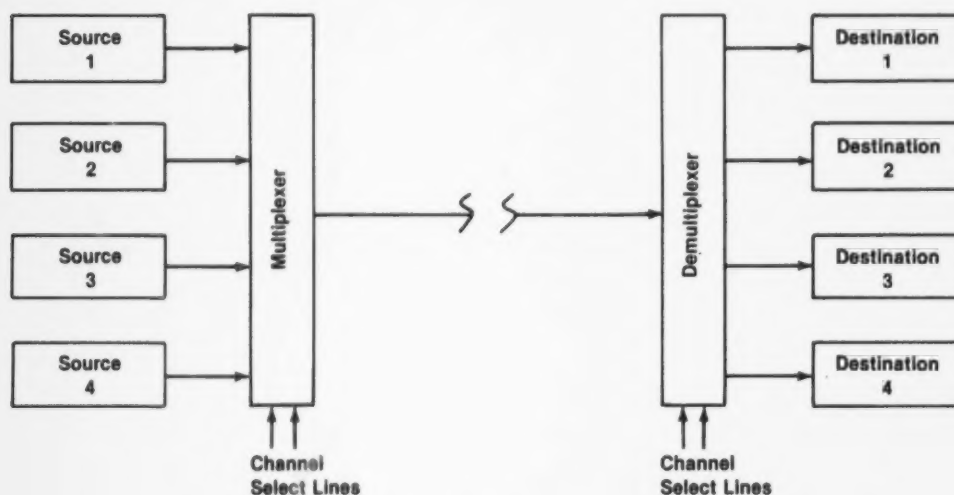
FIGURE 10



## INFORMATION SHEET

- D. Multiplexers/demultiplexers can also be constructed with IC chips with channel select lines that continually count through the channels to make sure the multiplexer and demultiplexer are on the same channel at the same time. (Figure 11)

FIGURE 11



- E. Multiplexers and demultiplexers have traditionally been connected with a conductor, but their construction is rapidly changing to fiber optics.

### XII. Fiber optics

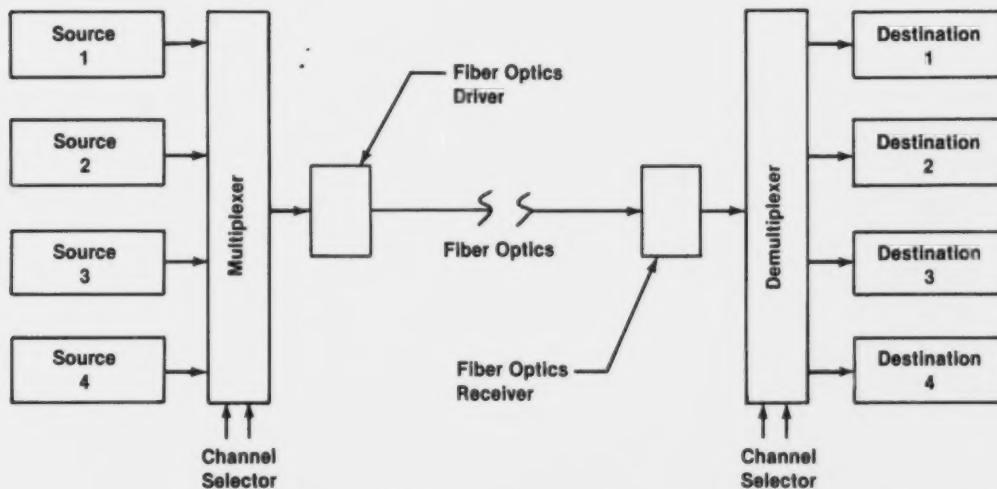
- A. Fiber optics is a technology that uses a protected cable to transmit light down a fiber core encased in a dark shield known as cladding.
- B. Since fiber optics produces devices that are small and neat, almost weightless, and free from the effects of static electricity and radio wave interference, the technology is perfect for digital components.
- C. A fiber optic device uses light to represent 1, and the absence of light to represent 0, so these devices are made to order for digital applications.

## INFORMATION SHEET

- D. LEDs can drive fiber optics, and light sensitive transistors can be used as receivers for fiber optics. (Figure 12)

(NOTE: Figure 12 shows a multiplexer/demultiplexer circuit using an optic fiber between them.)

FIGURE 12



- E. Fiber optics technology is new and was once expensive, but as applications expand, and as technicians become more experienced with fiber optics, the field is expanding and will soon be common to a multitude of electronic applications.

## Decimal/Binary Equivalents

| DECIMAL | BINARY | DECIMAL | BINARY | DECIMAL | BINARY |
|---------|--------|---------|--------|---------|--------|
| 0       | 0000   | 6       | 0110   | 11      | 1011   |
| 2       | 0010   | 7       | 0111   | 12      | 1100   |
| 3       | 0011   | 8       | 1000   | 13      | 1101   |
| 4       | 0100   | 9       | 1001   | 14      | 1110   |
| 5       | 0101   | 10      | 1010   | 15      | 1111   |

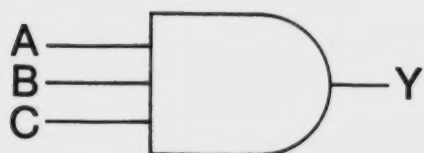
Moving left, each place value in the binary system doubles in value, and that is what is meant by a base 2 numbering system

|     |    |    |    |    |    |    |   |
|-----|----|----|----|----|----|----|---|
| x2  | x2 | x2 | x2 | x2 | x2 | x2 |   |
| 128 | 64 | 32 | 16 | 8  | 4  | 2  | 1 |

When a 0 appears in a place value, there is no number value, but when a 1 appears in a place value, the number value is equal to the place value and the number value is the total of all the place values that have a 1 in them

|      |     |     |     |    |    |    |   |   |   |   |       |
|------|-----|-----|-----|----|----|----|---|---|---|---|-------|
| 1024 | 512 | 256 | 128 | 64 | 32 | 16 | 8 | 4 | 2 | 1 |       |
| 0    | 0   | 0   | 0   | 0  | 0  | 0  | 1 | 0 | 1 | 0 | = 10  |
| 0    | 0   | 1   | 0   | 0  | 0  | 0  | 0 | 0 | 0 | 0 | = 256 |
| 0    | 0   | 1   | 1   | 1  | 1  | 1  | 1 | 1 | 0 | 0 | = 508 |

## AND Gate Symbol and Truth Table



$$ABC = Y$$

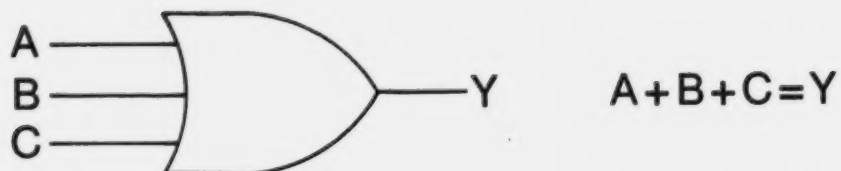
Symbol

| A | B | C | Y |
|---|---|---|---|
| 0 | 0 | 0 | 0 |
| 0 | 0 | 1 | 0 |
| 0 | 1 | 0 | 0 |
| 0 | 1 | 1 | 0 |
| 1 | 0 | 0 | 0 |
| 1 | 0 | 1 | 0 |
| 1 | 1 | 0 | 0 |
| 1 | 1 | 1 | 1 |

Truth Table



## OR Gate Symbol and Truth Table

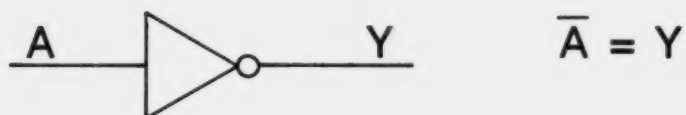


Symbol

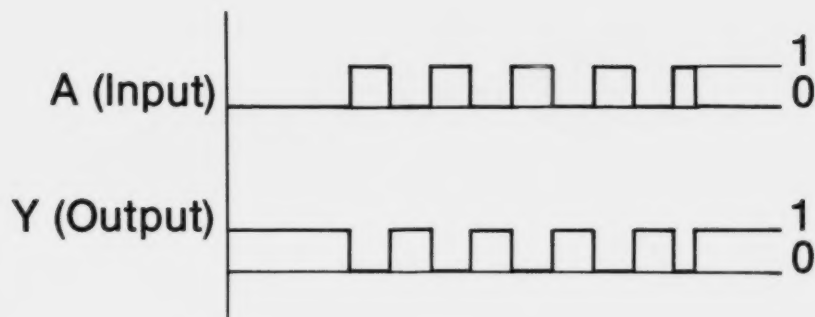
| A | B | C | Y |
|---|---|---|---|
| 0 | 0 | 0 | 0 |
| 0 | 0 | 1 | 1 |
| 0 | 1 | 0 | 1 |
| 0 | 1 | 1 | 1 |
| 1 | 0 | 0 | 1 |
| 1 | 0 | 1 | 1 |
| 1 | 1 | 0 | 1 |
| 1 | 1 | 1 | 1 |

Truth Table

# NOT Gate (Inverter)



Symbol

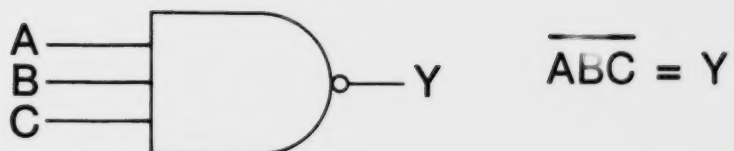


| A | Y |
|---|---|
| 0 | 1 |
| 1 | 0 |

Truth Table

0 = Logic Low    1 = Logic High

## NAND Gate Symbol and Truth Table

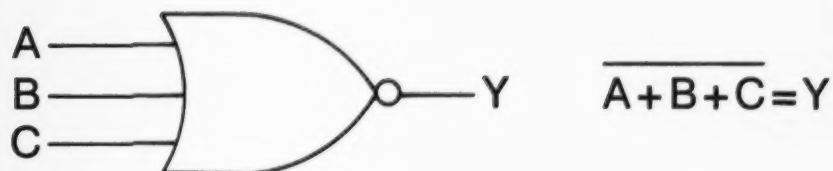


Symbol

| A | B | C | Y |
|---|---|---|---|
| 0 | 0 | 0 | 1 |
| 0 | 0 | 1 | 1 |
| 0 | 1 | 0 | 1 |
| 0 | 1 | 1 | 1 |
| 1 | 0 | 0 | 1 |
| 1 | 0 | 1 | 1 |
| 1 | 1 | 0 | 1 |
| 1 | 1 | 1 | 0 |

Truth Table

## NOR Gate Symbol and Truth Table

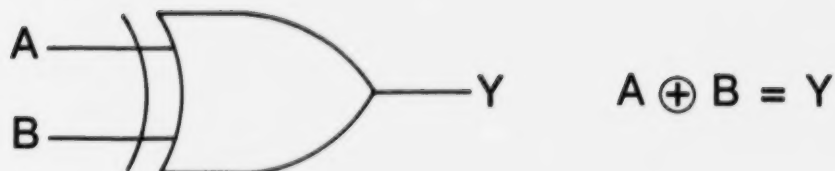


Symbol

| A | B | C | Y |
|---|---|---|---|
| 0 | 0 | 0 | 1 |
| 0 | 0 | 1 | 0 |
| 0 | 1 | 0 | 0 |
| 0 | 1 | 1 | 0 |
| 1 | 0 | 0 | 0 |
| 1 | 0 | 1 | 0 |
| 1 | 1 | 0 | 0 |
| 1 | 1 | 1 | 0 |

Truth Table

## Exclusive-OR Gate Symbol and Truth Table

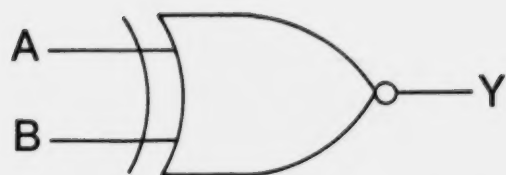


Symbol

| A | B | $A \oplus B$ |
|---|---|--------------|
| 0 | 0 | 0            |
| 0 | 1 | 1            |
| 1 | 0 | 1            |
| 1 | 1 | 0            |

Truth Table

## Exclusive-NOR Gate Symbol and Truth Table



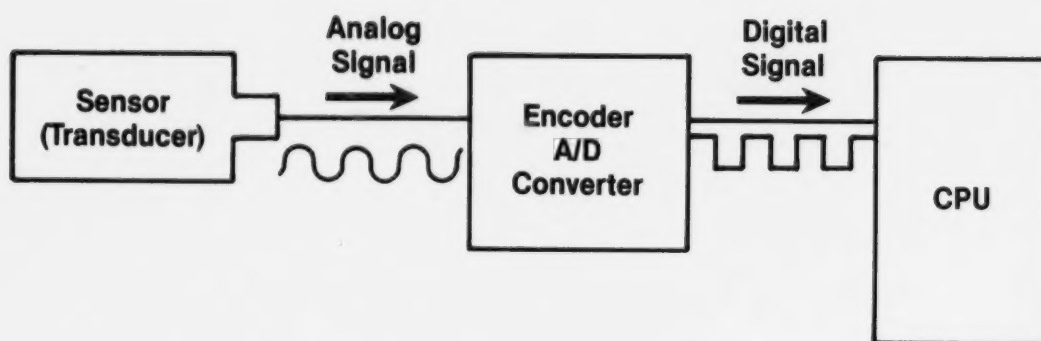
$$\overline{A \oplus B} = Y$$

Symbol

| A | B | $\overline{A \oplus B}$ |
|---|---|-------------------------|
| 0 | 0 | 1                       |
| 0 | 1 | 0                       |
| 1 | 0 | 0                       |
| 1 | 1 | 1                       |

Truth Table

# A/D Converter



# DIGITAL ELECTRONICS UNIT V

## ASSIGNMENT SHEET #1 — COMPLETE TRUTH TABLES FOR COMMON LOGIC DEVICES

Directions: The following truth tables are for logic gates used in various automotive applications. Study the tables, and complete them.

A. AND gate—

| A | B | C | Y |
|---|---|---|---|
| 0 | 0 | 0 |   |
| 0 | 0 | 1 |   |
| 0 | 1 | 0 |   |
| 0 | 1 | 1 |   |
| 1 | 0 | 0 |   |
| 1 | 0 | 1 |   |
| 1 | 1 | 0 |   |
| 1 | 1 | 1 |   |

B. OR gate—

| A | B | C | Y |
|---|---|---|---|
| 0 | 0 | 0 |   |
| 0 | 0 | 1 |   |
| 0 | 1 | 0 |   |
| 0 | 1 | 1 |   |
| 1 | 0 | 0 |   |
| 1 | 0 | 1 |   |
| 1 | 1 | 0 |   |
| 1 | 1 | 1 |   |

C. NOT gate—

| A | Y |
|---|---|
| 0 |   |
| 1 |   |

D. NAND gate—

| A | B | C | Y |
|---|---|---|---|
| 0 | 0 | 0 |   |
| 0 | 0 | 1 |   |
| 0 | 1 | 0 |   |
| 0 | 1 | 1 |   |
| 1 | 0 | 0 |   |
| 1 | 0 | 1 |   |
| 1 | 1 | 0 |   |
| 1 | 1 | 1 |   |

E. NOR gate—

| A | B | C | Y |
|---|---|---|---|
| 0 | 0 | 0 |   |
| 0 | 0 | 1 |   |
| 0 | 1 | 0 |   |
| 0 | 1 | 1 |   |
| 1 | 0 | 0 |   |
| 1 | 0 | 1 |   |
| 1 | 1 | 0 |   |
| 1 | 1 | 1 |   |

F. EXCLUSIVE-OR gate—

| A | B | Y |
|---|---|---|
| 0 | 0 |   |
| 0 | 1 |   |
| 1 | 0 |   |
| 1 | 1 |   |



# DIGITAL ELECTRONICS UNIT V

## ANSWERS TO ASSIGNMENT SHEETS

### Assignment Sheet #1

A. AND gate—

| A | B | C | Y |
|---|---|---|---|
| 0 | 0 | 0 | 0 |
| 0 | 0 | 1 | 0 |
| 0 | 1 | 0 | 0 |
| 0 | 1 | 1 | 0 |
| 1 | 0 | 0 | 0 |
| 1 | 0 | 1 | 0 |
| 1 | 1 | 0 | 0 |
| 1 | 1 | 1 | 1 |

B. OR gate—

| A | B | C | Y |
|---|---|---|---|
| 0 | 0 | 0 | 0 |
| 0 | 0 | 1 | 1 |
| 0 | 1 | 0 | 1 |
| 0 | 1 | 1 | 1 |
| 1 | 0 | 0 | 1 |
| 1 | 0 | 1 | 1 |
| 1 | 1 | 0 | 1 |
| 1 | 1 | 1 | 1 |

C. NOT gate—

| A | Y |
|---|---|
| 0 | 1 |
| 1 | 0 |

D. NAND gate—

| A | B | C | Y |
|---|---|---|---|
| 0 | 0 | 0 | 1 |
| 0 | 0 | 1 | 1 |
| 0 | 1 | 0 | 1 |
| 0 | 1 | 1 | 1 |
| 1 | 0 | 0 | 1 |
| 1 | 0 | 1 | 1 |
| 1 | 1 | 0 | 1 |
| 1 | 1 | 1 | 0 |

E. NOR gate—

| A | B | C | Y |
|---|---|---|---|
| 0 | 0 | 0 | 1 |
| 0 | 0 | 1 | 0 |
| 0 | 1 | 0 | 0 |
| 0 | 1 | 1 | 0 |
| 1 | 0 | 0 | 0 |
| 1 | 0 | 1 | 0 |
| 1 | 1 | 0 | 0 |
| 1 | 1 | 1 | 0 |

F. EXCLUSIVE-OR gate—

| A | B | Y |
|---|---|---|
| 0 | 0 | 0 |
| 0 | 1 | 1 |
| 1 | 0 | 1 |
| 1 | 1 | 0 |

## DIGITAL ELECTRONICS UNIT V

### JOB SHEET #1 — CONSTRUCT AND TEST AN “AND” GATE CIRCUIT

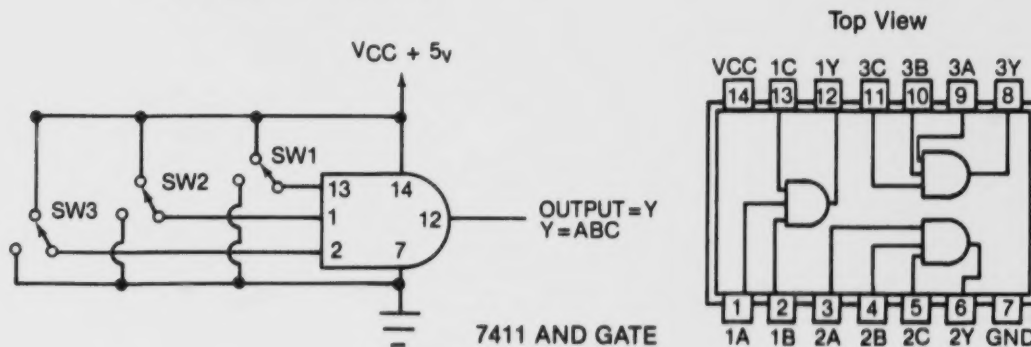
#### A. Equipment and materials

1. SN7411 triple 3-input positive-AND gates
2. Three SPDT switches
3. DC power supply (+5 Volt)
4. Multimeter
5. Proto-board or equipment system for connecting ICs
6. LED and a 470 ohm resistor (optional)
7. Pencil
8. Safety glasses

#### B. Procedure

1. Put on safety glasses.
2. Connect the following logic AND gate circuit.

(NOTE: This device, 7411, contains three AND gates on one chip, but only one of the gates will be tested.)



3. Check with your multimeter to be sure switches are as shown in the above diagram.

(NOTE: The switches may be replaced by simply connecting the inputs to +5 volts or ground.)

## JOB SHEET #1

4. Connect the multimeter to the output of the gate.

(NOTE: A visual output indication may be made by placing an LED and a series resistor [approximately 470 ohms] from the output to ground. The diodes cathode must be connected to ground.)

5. Complete the following truth table by switching the three input switches into all possible combinations and recording whether the output is a "1" (high voltage) or a "0" (low voltage).

| SW-1<br>Input A | SW-2<br>Input B | SW-3<br>Input C | Y<br>Output |
|-----------------|-----------------|-----------------|-------------|
| 0               | 0               | 0               |             |
|                 |                 |                 |             |
|                 |                 |                 |             |
|                 |                 |                 |             |
|                 |                 |                 |             |
|                 |                 |                 |             |
|                 |                 |                 |             |
| 1               | 1               | 1               |             |

6. Compare the output results with the truth table for an AND gate.

☐ Have your instructor check your work.

7. Return equipment and materials to their proper storage area.

## DIGITAL ELECTRONICS UNIT V

### JOB SHEET #2 — CONSTRUCT AND TEST AN "OR" GATE CIRCUIT

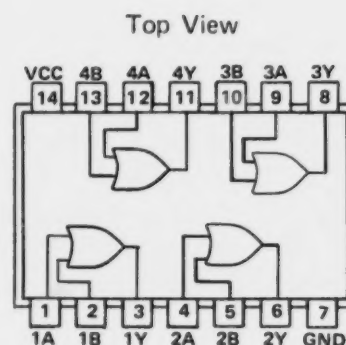
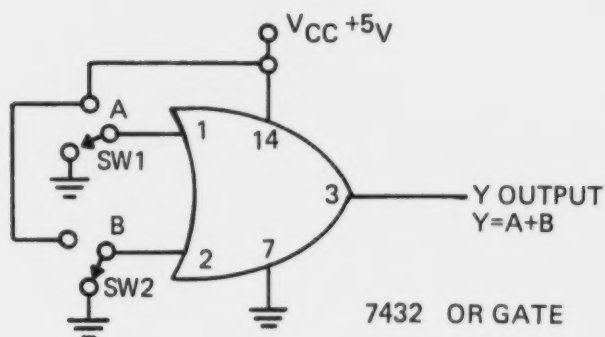
#### A. Equipment and materials

1. SN7432 Quadruple 2-input positive-OR gates
2. 2-SPDT switches
3. DC power supply
4. Multimeter
5. Proto-board or equipment system for connecting ICs
6. LED and a 470 ohm resistor (optional)
7. Pencil
8. Safety glasses

#### B. Procedure

1. Put on safety glasses.
2. Connect the following logic OR circuit.

(NOTE: This device, 7432, contains four OR gates on one chip but only one of the gates will be tested.)



3. Check with your multimeter to be sure switches are as shown in the above diagram.

## JOB SHEET #2

4. Connect the multimeter (DC volts) to the output of the gate.

(NOTE: A visual output indication may be made by placing an LED and a series resistor [approximately 470 ohms] from the output to ground. The diodes cathode must be connected to ground.)

5. Complete the following truth table by switching the two input switches into all possible combinations and record whether the output is a "1" (high voltage) or a "0" (low voltage).

| SW-1<br>Input A | SW-2<br>Input B | Y<br>Output |
|-----------------|-----------------|-------------|
| 0               | 0               |             |
|                 |                 |             |
|                 |                 |             |
| 1               | 1               |             |

6. Compare the output results with the truth table for an OR gate.

☐ Have your instructor check your work.

7. Return equipment and materials to their proper storage area.

## DIGITAL ELECTRONICS UNIT V

### JOB SHEET #3 — CONSTRUCT AND TEST A “NAND” GATE CIRCUIT

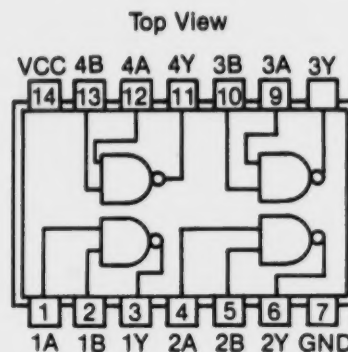
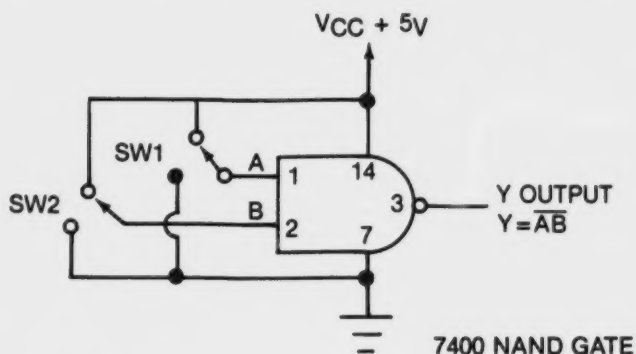
#### A. Equipment and materials

1. SN7400 Quadruple 2-input positive-NAND gates
2. 2 SPDT switches
3. Regulated DC power supply
4. Multimeter
5. Proto-board or equipment system for connecting ICs
6. LED and a 470 ohm resistor (optional)
7. Pencil
8. Safety glasses

#### B. Procedure

1. Put on safety glasses.
2. Connect the following logic NAND gate circuit.

(NOTE: Only one of the four gates on the chip will be tested. This device, SN7400, contains four NAND gates on one chip but only one of the gates will be tested.)



3. Check with your multimeter to be sure switches are as shown in the above diagram.

## JOB SHEET #3

4. Connect the multimeter to the output of the gate.

(NOTE: A visual output indication may be made by placing an LED and a series resistor [approximately 470 ohms] from the output to ground. The diodes cathode must be connected to ground.)

5. Complete the following truth table by switching the two input switches into all possible combinations and record whether the output is a "1" (high voltage) or a "0" (low voltage).

| SW-1<br>Input A | SW-2<br>Input B | Y<br>Output |
|-----------------|-----------------|-------------|
| 0               | 0               |             |
|                 |                 |             |
|                 |                 |             |
| 1               | 1               |             |

6. Compare the output results with the truth table for NAND gate.

☐ Have your instructor check your work.

7. Return equipment and materials to their proper storage area.

## DIGITAL ELECTRONICS UNIT V

### JOB SHEET #4 — CONSTRUCT AND TEST A “NOR” GATE CIRCUIT

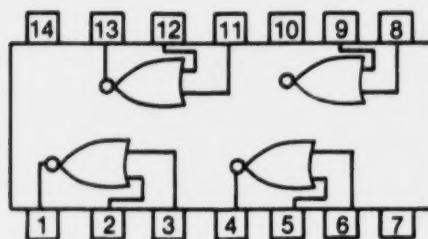
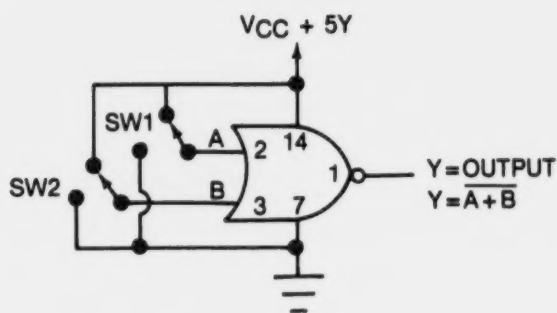
#### A. Equipment and materials

1. SN7402 Quadruple 2-input NOR gate
2. Two SPDT switches
3. Regulated DC power supply
4. Multimeter
5. Proto-board
6. LED and a 470 ohm resistor (optional)
7. Pencil
8. Safety glasses

#### B. Procedure

1. Put on safety glasses.
2. Connect the following logic NOR gate circuit.

(NOTE: Only one of the four gates on the chip will be tested. This device, SN7402, contains four NOR gates on one chip.)



3. Apply power.
4. Check with your multimeter to be sure switches are as shown in the diagram above.



## JOB SHEET #4

5. Connect the multimeter to the output of the gate.

(NOTE: A visual output indication may be made by placing an LED and a series resistor [approximately  $470\ \Omega$ ] from the output to ground. The cathode of the LED must be connected to ground.)

6. Complete the following truth table by changing the inputs with the switches. Record all possible combinations of inputs with their respective outputs in the chart below.

| SW-1<br>Input A | SW-2<br>Input B | Y<br>Output |
|-----------------|-----------------|-------------|
| 0               | 0               |             |
| 0               | 1               |             |
| 1               | 0               |             |
| 1               | 1               |             |

7. Compare the output results to that of an:

- a. "OR" circuit. \_\_\_\_\_
- b. "AND" circuit. \_\_\_\_\_
- c. "NAND" circuit. \_\_\_\_\_

☐ Have your instructor check your work.

8. Return equipment and materials to their proper storage area.

## DIGITAL ELECTRONICS UNIT V

### JOB SHEET #5 — CONSTRUCT AND TEST AN "EXCLUSIVE-OR" GATE CIRCUIT

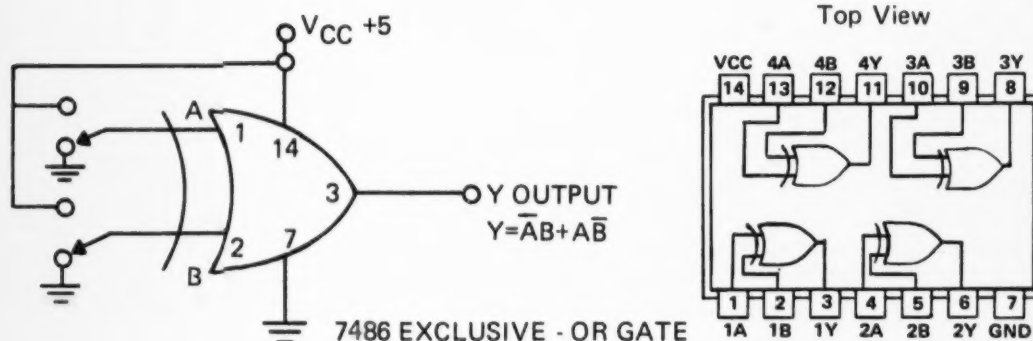
#### A. Equipment and materials needed

1. SN7485 Quadruple 2-Input Exclusive-OR gate
2. Two SPDT switches
3. Regulated DC power supply
4. Multimeter
5. Proto-board or equipment system for connecting ICs
6. LED and a 470 ohm resistor (optional)
7. Pencil
8. Safety glasses

#### B. Procedure

1. Put on safety glasses.
2. Wire the following logic exclusive OR gate circuit.

(NOTE: This device, SN7485, contains four Exclusive-OR gates on one chip, but only one of the gates will be tested.)



3. Check with your multimeter to be sure switches are as shown in the above diagram.

## JOB SHEET #5

4. Connect the multimeter to the output of the gate.

(NOTE: A visual output indication may be made by placing an LED and a series resistor [approximately 470 ohms] from the output to ground. The diodes cathode must be connected to ground.)

5. Complete the following truth table by switching the two inputs into all possible combinations and recording whether the output is a "1" (high voltage) or a "0" (low voltage).

| SW-1<br>Input A | SW-2<br>Input B | Y<br>Output |
|-----------------|-----------------|-------------|
| 0               | 0               |             |
|                 |                 |             |
|                 |                 |             |
| 1               | 1               |             |

6. Compare the output results with the truth table for an EXCLUSIVE-OR gate.

☐ Have your instructor check your work.

7. Return equipment and materials to their proper storage area.

## DIGITAL ELECTRONICS UNIT V

### JOB SHEET #6 — VERIFY "OR GATE" OPERATION IN A COOLING FAN CIRCUIT

#### A. Equipment and materials

1. Vehicle as selected by instructor
2. Appropriate service manual
3. Basic hand tools
4. DVOM
5. Jumper leads
6. Fender covers
7. Pencil
8. Safety glasses

#### B. Procedure

1. Put on safety glasses.
2. Bring vehicle into shop area, open hood, and install fender covers.
3. Block drive wheels, and install exhaust removal system.
4. Locate the cooling fan wiring diagram in your service manual.
5. Identify and locate all sensors or switches that are capable of turning on the radiator cooling fan.

(NOTE: If the vehicle is equipped with air conditioning, remember that the cooling fan is generally turned on whenever the air conditioning is on.)

6. Check your wiring diagram, and one by one isolate the possible sources for turning on the cooling fan.
7. Supply either ground or 12-volt power, whichever is demonstrated in the circuit diagram, until you cause the fan to operate in all possible configurations.

**JOB SHEET #6**

8. Explain in your own words how the cooling fan system works as an "Or Gate" function: \_\_\_\_\_

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☐ Have your instructor check your work.

9. Remove fender pads, and secure the vehicle.
10. Return tools and materials to proper storage.

# DIGITAL ELECTRONICS UNIT V

## PRACTICAL TEST #1 JOB SHEET #1 — CONSTRUCT AND TEST AN "AND" GATE CIRCUIT

Student's name \_\_\_\_\_

Date \_\_\_\_\_

Evaluator's name \_\_\_\_\_

Attempt no. \_\_\_\_\_

Student instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

### PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:

|                                                        | YES                         | NO                       |
|--------------------------------------------------------|-----------------------------|--------------------------|
| 1. Wore safety glasses.                                | 1. <input type="checkbox"/> | <input type="checkbox"/> |
| 2. Connected circuit properly.                         | 2. <input type="checkbox"/> | <input type="checkbox"/> |
| 3. Verified circuit structure with multimeter.         | 3. <input type="checkbox"/> | <input type="checkbox"/> |
| 4. Verified and recorded "AND" gate output.            | 4. <input type="checkbox"/> | <input type="checkbox"/> |
| 5. Completed truth table.                              | 5. <input type="checkbox"/> | <input type="checkbox"/> |
| 6. Compared truth table results with proper reference. | 6. <input type="checkbox"/> | <input type="checkbox"/> |
| 7. Secured equipment and materials.                    | 7. <input type="checkbox"/> | <input type="checkbox"/> |

Evaluator's comments: \_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

## JOB SHEET #1 PRACTICAL TEST

### PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another test procedure must be submitted for evaluation.)

Criteria:

|                         |                           |                          |                                  |               |
|-------------------------|---------------------------|--------------------------|----------------------------------|---------------|
| Tool and Equipment Use  | Excellent<br>4            | Good<br>3                | Fair<br>2                        | Poor<br>1     |
| Circuit Output Testing  | Well Done<br>4            | Acceptably Done<br>3     | Poorly Done<br>2                 | Improper<br>1 |
| Truth Table Preparation | Complete and Correct<br>4 | Acceptable<br>3          | Incomplete and/or Incorrect<br>2 | Improper<br>1 |
| Safety                  | Well Observed<br>4        | Acceptably Observed<br>3 | Improperly Observed<br>2         | Careless<br>1 |

EVALUATOR'S COMMENTS: \_\_\_\_\_

#### PERFORMANCE EVALUATION KEY

- 4 — Skilled — Can perform job with no additional training.
- 3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
- 2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
- 1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

## DIGITAL ELECTRONICS UNIT V

### PRACTICAL TEST #2 JOB SHEET #2 — CONSTRUCT AND TEST AN "OR" GATE CIRCUIT

Student's name \_\_\_\_\_

Date \_\_\_\_\_

Evaluator's name \_\_\_\_\_

Attempt no. \_\_\_\_\_

Student instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

#### PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:

|                                                        | YES                         | NO                       |
|--------------------------------------------------------|-----------------------------|--------------------------|
| 1. Wore safety glasses.                                | 1. <input type="checkbox"/> | <input type="checkbox"/> |
| 2. Connected circuit properly.                         | 2. <input type="checkbox"/> | <input type="checkbox"/> |
| 3. Verified circuit structure with multimeter.         | 3. <input type="checkbox"/> | <input type="checkbox"/> |
| 4. Verified and recorded "OR" gate output.             | 4. <input type="checkbox"/> | <input type="checkbox"/> |
| 5. Completed truth table.                              | 5. <input type="checkbox"/> | <input type="checkbox"/> |
| 6. Compared truth table results with proper reference. | 6. <input type="checkbox"/> | <input type="checkbox"/> |
| 7. Secured equipment and materials.                    | 7. <input type="checkbox"/> | <input type="checkbox"/> |

Evaluator's comments: \_\_\_\_\_

 \_\_\_\_\_  
 \_\_\_\_\_



## JOB SHEET #2 PRACTICAL TEST

### PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another test procedure must be submitted for evaluation.)

Criteria:

|                         |                           |                          |                                  |               |
|-------------------------|---------------------------|--------------------------|----------------------------------|---------------|
| Tool and Equipment Use  | Excellent<br>4            | Good<br>3                | Fair<br>2                        | Poor<br>1     |
| Circuit Output Testing  | Well Done<br>4            | Acceptably Done<br>3     | Poorly Done<br>2                 | Improper<br>1 |
| Truth Table Preparation | Complete and Correct<br>4 | Acceptable<br>3          | Incomplete and/or Incorrect<br>2 | Improper<br>1 |
| Safety                  | Well Observed<br>4        | Acceptably Observed<br>3 | Improperly Observed<br>2         | Careless<br>1 |

EVALUATOR'S COMMENTS: \_\_\_\_\_

#### PERFORMANCE EVALUATION KEY

- 4 — Skilled — Can perform job with no additional training.
- 3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
- 2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
- 1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

## DIGITAL ELECTRONICS UNIT V

### PRACTICAL TEST #3 JOB SHEET #3 — CONSTRUCT AND TEST AN "NAND" GATE CIRCUIT

Student's name \_\_\_\_\_

Date \_\_\_\_\_

Evaluator's name \_\_\_\_\_

Attempt no. \_\_\_\_\_

Student instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

#### PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:

|                                                        | YES                         | NO                       |
|--------------------------------------------------------|-----------------------------|--------------------------|
| 1. Wore safety glasses.                                | 1. <input type="checkbox"/> | <input type="checkbox"/> |
| 2. Connected circuit properly.                         | 2. <input type="checkbox"/> | <input type="checkbox"/> |
| 3. Verified circuit structure with multimeter.         | 3. <input type="checkbox"/> | <input type="checkbox"/> |
| 4. Verified and recorded "NAND" gate output.           | 4. <input type="checkbox"/> | <input type="checkbox"/> |
| 5. Completed truth table.                              | 5. <input type="checkbox"/> | <input type="checkbox"/> |
| 6. Compared truth table results with proper reference. | 6. <input type="checkbox"/> | <input type="checkbox"/> |
| 7. Secured equipment and materials.                    | 7. <input type="checkbox"/> | <input type="checkbox"/> |

Evaluator's comments: \_\_\_\_\_

 \_\_\_\_\_  
 \_\_\_\_\_

## JOB SHEET #3 PRACTICAL TEST

### PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another test procedure must be submitted for evaluation.)

Criteria:

|                         |                           |                          |                                  |               |
|-------------------------|---------------------------|--------------------------|----------------------------------|---------------|
| Tool and Equipment Use  | Excellent<br>4            | Good<br>3                | Fair<br>2                        | Poor<br>1     |
| Circuit Output Testing  | Well Done<br>4            | Acceptably Done<br>3     | Poorly Done<br>2                 | Improper<br>1 |
| Truth Table Preparation | Complete and Correct<br>4 | Acceptable<br>3          | Incomplete and/or Incorrect<br>2 | Improper<br>1 |
| Safety                  | Well Observed<br>4        | Acceptably Observed<br>3 | Improperly Observed<br>2         | Careless<br>1 |

EVALUATOR'S COMMENTS: \_\_\_\_\_

#### PERFORMANCE EVALUATION KEY

- 4 — Skilled — Can perform job with no additional training.
- 3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
- 2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
- 1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

# DIGITAL ELECTRONICS UNIT V

## PRACTICAL TEST #4 JOB SHEET #4 — CONSTRUCT AND TEST A "NOR" GATE CIRCUIT

Student's name \_\_\_\_\_

Date \_\_\_\_\_

Evaluator's name \_\_\_\_\_

Attempt no. \_\_\_\_\_

Student instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

### PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:

|                                                        | YES                         | NO                       |
|--------------------------------------------------------|-----------------------------|--------------------------|
| 1. Wore safety glasses.                                | 1. <input type="checkbox"/> | <input type="checkbox"/> |
| 2. Connected circuit properly.                         | 2. <input type="checkbox"/> | <input type="checkbox"/> |
| 3. Verified circuit structure with multimeter.         | 3. <input type="checkbox"/> | <input type="checkbox"/> |
| 4. Verified and recorded "NOR" gate output.            | 4. <input type="checkbox"/> | <input type="checkbox"/> |
| 5. Completed truth table.                              | 5. <input type="checkbox"/> | <input type="checkbox"/> |
| 6. Compared truth table results with proper reference. | 6. <input type="checkbox"/> | <input type="checkbox"/> |
| 7. Secured equipment and materials.                    | 7. <input type="checkbox"/> | <input type="checkbox"/> |

Evaluator's comments: \_\_\_\_\_

 \_\_\_\_\_  
 \_\_\_\_\_

## JOB SHEET #4 PRACTICAL TEST

### PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another test procedure must be submitted for evaluation.)

Criteria:

|                         |                           |                          |                                  |               |
|-------------------------|---------------------------|--------------------------|----------------------------------|---------------|
| Tool and Equipment Use  | Excellent<br>4            | Good<br>3                | Fair<br>2                        | Poor<br>1     |
| Circuit Output Testing  | Well Done<br>4            | Acceptably Done<br>3     | Poorly Done<br>2                 | Improper<br>1 |
| Truth Table Preparation | Complete and Correct<br>4 | Acceptable<br>3          | Incomplete and/or Incorrect<br>2 | Improper<br>1 |
| Safety                  | Well Observed<br>4        | Acceptably Observed<br>3 | Improperly Observed<br>2         | Careless<br>1 |

EVALUATOR'S COMMENTS: \_\_\_\_\_

#### PERFORMANCE EVALUATION KEY

- 4 — Skilled — Can perform job with no additional training.
- 3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
- 2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
- 1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

## DIGITAL ELECTRONICS UNIT V

### PRACTICAL TEST #5 JOB SHEET #5 — CONSTRUCT AND TEST AN "EXCLUSIVE-OR" GATE CIRCUIT

Student's name \_\_\_\_\_

Date \_\_\_\_\_

Evaluator's name \_\_\_\_\_

Attempt no. \_\_\_\_\_

Student instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

#### PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

| The student:                                           | YES                         | NO                       |
|--------------------------------------------------------|-----------------------------|--------------------------|
| 1. Wore safety glasses.                                | 1. <input type="checkbox"/> | <input type="checkbox"/> |
| 2. Connected circuit properly.                         | 2. <input type="checkbox"/> | <input type="checkbox"/> |
| 3. Verified circuit structure with multimeter.         | 3. <input type="checkbox"/> | <input type="checkbox"/> |
| 4. Verified and recorded "EXCLUSIVE-OR" gate output.   | 4. <input type="checkbox"/> | <input type="checkbox"/> |
| 5. Completed truth table.                              | 5. <input type="checkbox"/> | <input type="checkbox"/> |
| 6. Compared truth table results with proper reference. | 6. <input type="checkbox"/> | <input type="checkbox"/> |
| 7. Secured equipment and materials.                    | 7. <input type="checkbox"/> | <input type="checkbox"/> |

Evaluator's comments: \_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

## JOB SHEET #5 PRACTICAL TEST

### PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another test procedure must be submitted for evaluation.)

Criteria:

|                         |                           |                          |                                  |               |
|-------------------------|---------------------------|--------------------------|----------------------------------|---------------|
| Tool and Equipment Use  | Excellent<br>4            | Good<br>3                | Fair<br>2                        | Poor<br>1     |
| Circuit Output Testing  | Well Done<br>4            | Acceptably Done<br>3     | Poorly Done<br>2                 | Improper<br>1 |
| Truth Table Preparation | Complete and Correct<br>4 | Acceptable<br>3          | Incomplete and/or Incorrect<br>2 | Improper<br>1 |
| Safety                  | Well Observed<br>4        | Acceptably Observed<br>3 | Improperly Observed<br>2         | Careless<br>1 |

EVALUATOR'S COMMENTS: \_\_\_\_\_

#### PERFORMANCE EVALUATION KEY

- 4 — Skilled — Can perform job with no additional training.
- 3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
- 2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
- 1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)



## DIGITAL ELECTRONICS UNIT V

### PRACTICAL TEST #6 JOB SHEET #6 — VERIFY "OR" GATE OPERATION IN A COOLING FAN CIRCUIT

Student's name \_\_\_\_\_

Date \_\_\_\_\_

Evaluator's name \_\_\_\_\_

Attempt no. \_\_\_\_\_

Student instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

#### PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:

|                                                   | YES                         | NO                       |
|---------------------------------------------------|-----------------------------|--------------------------|
| 1. Wore safety glasses.                           | 1. <input type="checkbox"/> | <input type="checkbox"/> |
| 2. Prepared vehicle safely.                       | 2. <input type="checkbox"/> | <input type="checkbox"/> |
| 3. Referenced service manual for wiring diagram.  | 3. <input type="checkbox"/> | <input type="checkbox"/> |
| 4. Isolated power sources for cooling fan.        | 4. <input type="checkbox"/> | <input type="checkbox"/> |
| 5. Operated fan in all configurations.            | 5. <input type="checkbox"/> | <input type="checkbox"/> |
| 6. Identified "OR" gate functions of cooling fan. | 6. <input type="checkbox"/> | <input type="checkbox"/> |
| 7. Secured vehicle, tools, and materials.         | 7. <input type="checkbox"/> | <input type="checkbox"/> |

Evaluator's comments: \_\_\_\_\_

 \_\_\_\_\_  
 \_\_\_\_\_



## JOB SHEET #6 PRACTICAL TEST

### PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another test procedure must be submitted for evaluation.)

Criteria:

|                        |                        |                          |                            |                   |
|------------------------|------------------------|--------------------------|----------------------------|-------------------|
| Tool and Equipment Use | Excellent<br>4         | Good<br>3                | Fair<br>2                  | Poor<br>1         |
| Wiring Diagram Reading | Complete<br>4          | Acceptable<br>3          | Confused<br>2              | Unacceptable<br>1 |
| Procedure              | Well Done<br>4         | Acceptably Done<br>3     | Poorly Done<br>2           | Unacceptable<br>1 |
| Safety                 | Properly Observed<br>4 | Acceptably Observed<br>3 | Incompletely Observed<br>2 | Careless<br>1     |

EVALUATOR'S COMMENTS: \_\_\_\_\_

#### PERFORMANCE EVALUATION KEY

- 4 — Skilled — Can perform job with no additional training.
- 3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
- 2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
- 1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

# DIGITAL ELECTRONICS UNIT V

## TEST

NAME \_\_\_\_\_

SCORE \_\_\_\_\_

1. Match terms related to digital electronics with their correct definitions.

- |                                                                                                       |                         |
|-------------------------------------------------------------------------------------------------------|-------------------------|
| _____a. Number system which has digits zero (0) and one (1) only                                      | 1. Logic high           |
| _____b. A single binary digit, 0 or 1                                                                 | 2. Word                 |
| _____c. A circuit that acts like a switch, either on or off                                           | 3. Binary number system |
| _____d. High voltage (usually five volts or more) representing binary 1                               | 4. Logic low            |
| _____e. Low voltage (usually 0 or near 0) representing binary 0                                       | 5. Bit                  |
| _____f. Summarizes the various combinations of input and corresponding output signals for logic gates | 6. Truth table          |
| _____g. A group of bits representing a complete piece of digital information                          | 7. Digital circuit      |

2. Complete statements concerning digital overview by circling the word(s) that best complete(s) each statement.

- a. There was a day when (**analog**, **AC**) devices made up the world of electronics and instrumentation.
- b. Analog devices use continuous (**resistance**, **voltages**) or currents to represent naturally occurring physical changes of temperature, pressure, air, speed, or a liquid level.
- c. In modern electronics and instrumentation (**computers**, **digital devices**) are being used more and more to measure and control many of the things formerly done by analog devices.
- d. Digital devices differ from analog devices in that digital voltages or currents are (**periodic**, **intermittent**), not continuous.
- e. Digital periodic voltage signals are at one of two allowed voltages for a short time, and these individual voltage level elements are called (**BITS**, **WORDS**).

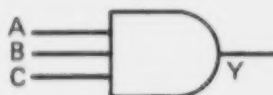
## TEST

- f. The two most common digital voltage levels are +5 volts and zero volts which can be used in a series of (**BITS, WORDS**) to make up what is called a data (**word, string**).
- g. Data (**words, strings**) can be transmitted from digital sensors to digital display devices to provide technicians with information vital for monitoring and evaluating operations of a single function or a system.
3. Select true statements concerning binary digits by placing an "X" beside each statement that is true.
- \_\_\_\_a. The individual BITS that make up a data word take their name from the two words Binary and digit.
- \_\_\_\_b. Since binary means two, a binary digit has only two numbers in it, and those numbers are 1 and 0.
- \_\_\_\_c. In digital circuits, +5 volts is often used to represent a binary 1, and 0 volts is used to represent a binary 0.
- \_\_\_\_d. Because a binary digit is either 1 or 0, binary circuits can be used to control opposing conditions such as a switch that is ON or OFF, a valve that is OPEN or CLOSED, a liquid that is HOT or COLD, and other opposite conditions.
- \_\_\_\_e. Binary bits are represented in a base 2 numbering system that permits bits to be used for measuring numerical values or quantities.
- \_\_\_\_f. The base 2 numbering system is not similar to the base 10 or decimal numbering system which we use every day.
- \_\_\_\_g. Because of the nature of the base 2 numbering system, digital bits can be used to represent numerical quantities, and also for digital control.
- \_\_\_\_h. When the bit values of 1 and 0 are used for digital control, the bit value of 1 or 0 is called a control base.
4. Solve problems concerning logic gates and truth tables by answering the following questions.
- a. What are the three basic logic gates?  
Answer: \_\_\_\_\_
- b. Logic gates are identified by symbols, but what do truth tables accomplish?  
Answer: \_\_\_\_\_

## TEST

5. Identify an AND gate by putting an "X" beside the AND gate symbol in the following illustrations.

\_\_\_\_ a.

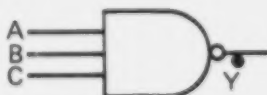


\_\_\_\_ b.



6. Identify an OR gate by putting an "X" beside the OR gate symbol in the following illustrations.

\_\_\_\_ a.



\_\_\_\_ b.



## TEST

7. Identify a NOT gate by putting an "X" beside the NOT gate symbol in the following illustrations.

\_\_\_\_ a.



\_\_\_\_ b.



8. Identify other basic logic gates by inserting the names NAND gate, NOR gate, EXCLUSIVE-OR gate or EXCLUSIVE-NOR gate beside the symbols that represent them.

\_\_\_\_ a.



\_\_\_\_ b.

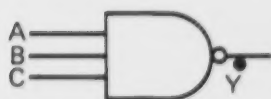


## TEST

\_\_\_\_c.



\_\_\_\_d.



9. Complete statements concerning D/A converters by circling the word(s) that best complete(s) each statement.
- Most automotive sensors generate (a **digital**, an **analog**) signal.
  - Before a computer can handle analog information, the analog data must be (**converted**, **deciphered**) to usable digital/binary information.
  - Most automotive computers work with an (**8-bit**, **16-bit**) register that has a binary capacity of 256 maximum representations.
  - An A/D converter receives an analog signal, converts it to a binary value, and then stores it in a #2 register where the computer compares it against a (**look-up table**, **parameter guide**) to determine the digital value.
  - An A/D converter uses a series of ("**Exclusive Or**", "**AND**") logic gates to do the comparisons, and when a perfect match is found, it yields a binary "O" in a #1 register.
10. Complete statements concerning D/A converters by circling the word(s) that best complete(s) each statement.
- Many automotive devices work on an analog signal, so to send digital information from the computer to an analog device requires a digital to analog (**conversion**, **interface**).

## TEST

- b. D/A converters convert a binary number into a corresponding analog voltage level that is proportional to a (**binary, decimal**) input number.
  - c. The most common D/A converters use 8-bit inputs, and the output voltage varies from 0 to (5 volts, 12 volts).
  - d. A simple D/A converter uses a (**serial, parallel**) input interface, and two operational amplifiers.
  - e. The analog output is a (**straight-line, stair-step**) voltage with the sampling rate as the determining factor for the value jumps between the (**steps, voltage input**).
11. Select true statements concerning multiplexing and demultiplexing by placing an "X" beside each statement that is true.
- \_\_\_\_\_a. In cases where several transducers are sending signals to a central processing unit, wiring would be complex and too much weight would be added to a system if each transducer had its own conductor.
  - \_\_\_\_\_b. To save weight and wiring complexity, multiplexers and demultiplexers allow several transducers to time-share a single transmission line.
  - \_\_\_\_\_c. One approach to multiplexing/demultiplexing is to use rotary switches so synchronized that the switch wipers are in the correct positions at all times.
  - \_\_\_\_\_d. Multiplexers/demultiplexers can also be constructed with IC chips with channel select lines that continually count through the channels to make sure the multiplexer and demultiplexer are on the same channel at the same time.
  - \_\_\_\_\_e. Multiplexers and demultiplexers have traditionally been connected with a conductor, but their construction is rapidly changing to fiber optics.
12. Complete statements concerning fiber optics by circling the word(s) that best complete(s) each statement.
- a. Fiber optics is a technology that uses a (**special tube, protected cable**) to transmit light down a fiber core encased in a dark shield known as cladding.
  - b. Since fiber optics produces devices that are small and neat, almost weightless, and free from the effects of static electricity and radio wave interference, the technology is perfect for (**digital, analog**) components.
  - c. A fiber optic device uses light to represent 1, and the absence of light to represent 0, so these devices are made to order for (**digital, analog**) applications.



## TEST

- d. LEDs can drive fiber optics, and (**light sensitive, normal**) transistors can be used as receivers for fiber optics.
- e. Fiber optics technology is new and was once (**ignored, expensive**), but as applications expand, and as technicians become more experienced with fiber optics, the field is expanding and will soon be common to a multitude of electronic applications.

(NOTE: If the following activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

- 13. Complete truth tables for common logic devices. (Assignment Sheet #1)
- 14. Demonstrate the ability to:
  - a. Construct and test an "AND" gate circuit. (Job Sheet #1)
  - b. Construct and test an "OR" gate circuit. (Job Sheet #2)
  - c. Construct and test a "NAND" gate circuit. (Job Sheet #3)
  - d. Construct and test a "NOR" gate circuit. (Job Sheet #4)
  - e. Construct and test an "EXCLUSIVE-OR" gate circuit. (Job Sheet #5)
  - f. Verify "OR" gate operation in a cooling fan circuit. (Job Sheet #6)

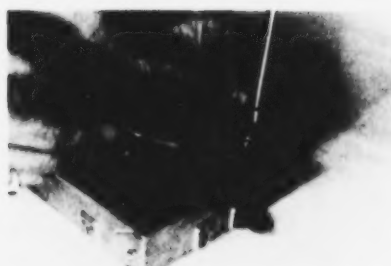


**DIGITAL ELECTRONICS  
UNIT V****ANSWERS TO TEST**

1.   a.    3                   e.    4  
      b.    5                   f.    6  
      c.    7                   g.    2  
      d.    1
  
2.   a.    Analog  
      b.    Voltages  
      c.    Digital devices  
      d.    Periodic  
      e.    BITS  
      f.    BITS, word  
      g.    Words
  
3.   a, b, c, d, e, g
  
4.   a.    The AND gate, the OR gate, and the NOT gate  
      b.    They show logic gate functions
  
5.   a
  
6.   b
  
7.   a
  
8.   a.    EXCLUSIVE-OR  
      b.    EXCLUSIVE-NOR  
      c.    NOR  
      d.    NAND
  
9.   a.    An analog  
      b.    Converted  
      c.    8-bit  
      d.    Look-up table  
      e.    "Exclusive Or"

## ANSWERS TO TEST

- 10.
  - a. Conversion
  - b. Binary
  - c. 5 volts
  - d. Parallel
  - e. Stair-step, steps
  
- 11. a, b, c, d, e
  
- 12.
  - a. Protected cable
  - b. Digital
  - c. Digital
  - d. Light sensitive
  - e. Expensive
  
- 13. Evaluated to the satisfaction of the instructor.
  
- 14. Job sheets evaluated according to the criteria in the practical tests.



## **AUTOMOTIVE MICROPROCESSORS**

### **UNIT VI**

#### **UNIT OBJECTIVE**

After the completion of this unit, the student should be able to discuss microprocessor architecture, and how an automotive computer communicates with sensors and other devices that help make an automotive electronic system. The students should also be able to explain the functions of transducers and encoders, remove and replace a PROM, identify ground and power circuits, repair terminals, and handle a CPU with proper grounding procedures. These competencies will be evidenced by correctly performing the procedures outlined in the job sheets, and by scoring a minimum of 85 percent on the unit test.

#### **SPECIFIC OBJECTIVES**

After completion of this unit, the student should be able to:

1. Match terms related to automotive microprocessors with their correct definitions.
2. Complete statements concerning computer hardware/software.
3. Select true statements concerning the computer as a decision center.
4. Solve problems concerning how a computer handles input/output.
5. Select true statements concerning guidelines for handling computers.
6. Select true statements concerning automotive microprocessor architecture.
7. Complete statements concerning serial and duplex serial data communications.
8. Complete statements concerning other data communication techniques.
9. Solve problems concerning parallel data communications.
10. Complete statements concerning transducers and encoders.
11. Select true statements concerning Weather Pack® connectors and locks.
12. Complete statements concerning microprocessor applications in automotive electronics.

**OBJECTIVE SHEET**

13. Demonstrate the ability to:
  - a. Remove and replace a PROM using proper grounding protection. (Job Sheet #1)
  - b. Test integrity of ground and power circuits. (Job Sheet #2)
  - c. Repair connector terminals. (Job Sheet #3)

## **AUTOMOTIVE MICROPROCESSORS UNIT VI**

### **SUGGESTED ACTIVITIES**

- A. Provide students with objective sheet.
- B. Provide students with information sheet.
- C. Make transparencies.
- D. Discuss unit and specific objectives.
- E. Discuss information sheet.
- F. Discuss and demonstrate the procedures outlined in the job sheets.
- G. Arrange for vehicles and appropriate service manuals so job sheets will reflect real-world troubleshooting.
- H. Point out multiple ECM grounds and duplicate power sources, and be sure to point out which power source is for long term memory, and which is a "key on" power source.
- I. Give test

### **REFERENCES USED IN DEVELOPING THIS UNIT**

- A. *EEC III EEC IV 5-DAY TECHNICIAN CERTIFICATION*. Dearborn, MI 48121: Ford Parts and Service Division, Training and Publications Department, 1985.
- B. *Electricity and Electronics, Fundamentals*. Highland Park, MI 48203: Service Training, Chrysler Corporation, 1984.
- C. *Servicing Vehicle Electronic Instruments*. Dearborn, MI 48121: Ford Parts and Service Division, Training and Publications Department, 1985.
- D. *Specialized Electronics Training*. Warren, MI 48090: Product Service Training, General Motors Corporation, 1984.

## **AUTOMOTIVE MICROPROCESSORS UNIT VI**

### **INFORMATION SHEET**

#### **I. Terms and definitions**

- A. BAUD rate — The measurement of the speed of data transmission along a communication link
- B. Burning — A process that etches certain predesigned circuits into a micro-computer chip
- C. Busses — Mechanical data links for transmission of data from various components in a computer system
- D. CPU (central processing unit) — The brains of a microcomputer where comparisons are made and command decisions executed
- E. Duplex serial data — Bi-directional data transmission that uses a clock pulse to determine whether a device is sending or receiving data on a shared data line
- F. Hardware — The physical components of a computer system
- G. Serial data — Data transmission that sends one bit of information at a time in a sequential order
- H. Software — The programs or compilers that address the computer memory required to perform a desired function
- I. Transducer — A device that changes one form of energy into another form of energy

#### **II. Computer hardware/software**

- A. The CPU (central processing unit) is the brains of a computer; it retrieves information to be processed, processes that information, performs functions, and stores information.
- B. As the name implies, ROM (read only memory) can be read from but not written to. It is a form of memory that can be used to store information only once, and is considered software.
- C. RAM (random access memory) is a computer's usable memory that can be read from and written to, and is the location where calculations and comparisons are stored for use.
- D. The PROM (programmable read only memory) chip, is valuable because it can have a variety of data parameters burned into its circuitry and be updated and changed to correct system problems.

## INFORMATION SHEET

- E. PROM data cannot be changed but an EPROM (erasable programmable read only memory) can be erased and reprogrammed.
- F. An EPROM is usually erased with an ultraviolet light, but burning PROMs or EPROMs requires sophisticated equipment.

### III. The computer as a decision center

- A. A computer works on a binary base 2 numbering system, and that means all data represents a YES/NO, ON/OFF condition that the computer uses to make decisions.
- B. Some computers working with artificial intelligence can reason, but an automotive computer can only compare an input value with a parameter stored in memory, and then make a decision.
- C. The major advantage of a computer is that it performs ON/OFF, YES/NO decision making with remarkable speed.

### IV. How a computer handles input/output

- A. A computer relies entirely on the data it receives from a source input device, and if the input information is inaccurate, then the output information will also be inaccurate, and this is better known as "garbage in, garbage out."
- B. To keep a computer from executing undesirable commands, there are safeguards called "error warnings," or, in the automotive field, "trouble codes."
- C. Trouble codes are designed to tell a technician that the input/output data that was processed did not meet the allowable parameters stored in memory.

### V. Guidelines for handling computers

- A. DON'T connect or disconnect any CPU components when the IGNITION KEY IS ON.
- B. DON'T connect or disconnect the CPU harness when the IGNITION KEY IS ON.

(NOTE: Most CPU codes are erased by removing the fuse that supplies power to the CPU long term memory.)

- C. DON'T leave the IGNITION KEY ON when working with microprocessors in:
  - 1. Electronic climate control modules.
  - 2. Electronic instrument cluster modules.

## INFORMATION SHEET

3. Cruise control modules.
4. Vehicle level ride control modules.

(NOTE: Always check the appropriate service manual for modules and microprocessors that require special handling.)

- D. DON'T test a CPU-controlled switch or sensor with a 12-volt source because some sensors attached to the CPU operate on what is called a 5 volt CPU TTL level reference voltage.

(NOTE: Most GM vehicles operate on the 5 volt CPU reference voltage, and any variance from that standard would be listed in an appropriate service manual.)

- E. When removing the CPU assembly from a vehicle, DO ground yourself with a ground clip with one end attached to your clothes, and the other end attached to the negative post of the battery or a chassis ground. (Figure 1)

FIGURE 1



- F. When working with a CPU on a workbench, DO ground yourself properly with a ground clip attached to your clothes, and the other end attached to a proper ground.

### VI. Automotive microprocessor architecture (Transparency 1)

- A. All CPUs have certain components in common:
  1. RAM
  2. ROM
  3. PROM
  4. Microprocessor



## INFORMATION SHEET

- B. RAM (Random Access Memory) is the only part of a computer which the central processor can read information from or write information to.
- C. ROM (Read Only Memory) is filled with data that is used for internal control of computer operations.
- D. PROM (Programmable Read Only Memory) is generally a removable component that can be used to correct problems or provide versatility.
- E. PROM is a section of memory that contains specific information about the engine fuel system, transmission, rear axle, emission system, and vehicle options.
- F. The CPU (Central Processing Unit) is the brains of the computer, and controls the address buss (for storage), retrieval of information, calculations, and output commands to sensors.
- G. The CPU also has a "board" with the harness connector receivers attached to the end of the board to provide a tight connection between the sensors and the CPU.
- H. On fuel injected engines, most CPUs contain an additional PROM which contains the back-up fuel programs that keep the engine operating in case of total system failure (limp home mode).

(NOTE: The extra PROM contains less specific vehicle data than the base PROM, and GM refers to this system as a CALPAC, calibrations package.)

- I. Another important CPU function is handling the full system voltage circuits (12 volts) by grounding the circuits to turn them ON/OFF.
- J. The CPU component that handles the higher voltage circuits is called a "Quad Driver," and there are usually three or four of these grounding devices in a CPU.
- K. Quad drivers are tested by measuring for a minimum resistance of 50,000 ohms between the quad driver terminal and the ECM case.

(NOTE: Be sure to follow service manual procedures because some resistance readings will be lower, and not all CPUs use quad drivers.)

### VII. Serial and duplex serial data communications (Transparency 2)

- A. Some advanced CPU systems incorporate a BCM (body computer) to manage support systems such as the ECC (electronic climate control), electronic instrument panel, and fuel data readout.

## INFORMATION SHEET

- B. Some vehicles use a serial data link between various computerized control modules, including the CPU, BCM, instrument panel, power module, ECC, and programmer.

(NOTE: The serial data link is used on GM 30 cars from 1986, and these include Buick Riviera, Oldsmobile Toronado, and Cadillac Eldorado and Seville.)

- C. In some systems, the CPU and the BCM use duplex serial data to communicate back and forth.
- D. Duplex serial data transmission is bi-directional, and uses one data line for both sending and receiving information.
- E. Each device on the ends of a duplex serial data line can transmit and receive data.
- F. The clock high voltage ON signal tells device one to send and device two to receive; the clock low voltage OFF signal tells device one to receive, and device two to send.

### VIII. Other data communication techniques

- A. Duplex serial communications have many applications, but UART (universal asynchronous receive and transmit) communications link have even more advanced applications.

(NOTE: The UART communications system is used on GM's Cadillac Allante.)

- B. The UART system sends a complicated duplex serial data stream that requires a system of protocol.
- C. Protocol means that each word position in a data stream corresponds to the same data parameter each time the data stream is transmitted.

Example: When the data stream third word position is TPS, and the fourth word position COOLANT SENSOR, then every time the data stream is transmitted, TPS will be in the third word position.

- D. Each device in the UART data link has a polling code, and when the BCM sends out that code, the device transmits its data.
- E. The UART system uses a 64-word data stream, and each device reads only the data words that it needs to respond to.

## INFORMATION SHEET

### IX. Parallel data communications

- A. Parallel data communications require a wire for every data bit in a computer, and very few systems use parallel data links.
- B. One parallel data link is used on the GM 30 car line with the shift indicator function, and in this system the shift indicator is displayed on the electronic instrument panel by LED or backlit fluorescences.

### X. Transducers and encoders (Transparency 3)

- A. Almost all automotive sensors are transducers in that they change other forms into electricity.  
  
Example: The coolant sensor changes heat into electricity, the TPS changes mechanical rotation into electricity, and the MAP sensor changes vacuum into electricity.
- B. The electricity from sensors is in an analog form, and must be converted into a digital form before the CPU can process the information.
- C. Conversion of analog signals to digital signals is accomplished by devices called "encoders."
- D. Encoders not only convert analog signals to digital signals, they "chop" digital data into binary bits of information for storage and manipulation by the CPU.
- E. Encoders are internal components of a computer, and cannot be serviced separately.

### XI. Weather Pack® connectors and locks

- A. To withstand the voltage spikes, shocks, and vibrations that an automotive CPU is subjected to, the modules are encased in special weatherproof materials, and have locks designed to assure tight connections for sensor inputs.

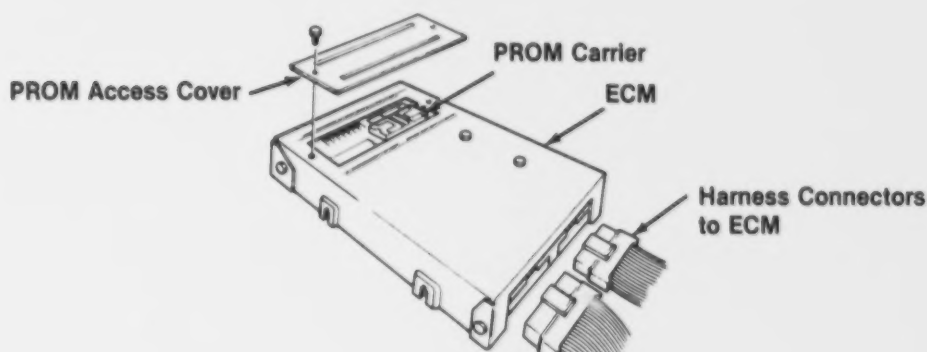
(NOTE: Weather Pack is a registered trademark of General Motors Corporation.)

- B. Corrosion on a terminal can raise the resistance of a circuit, and even a slight resistance increase can cause a voltage drop of a few millivolts, and affect the operation of the engine.
- C. Crimp type connectors, or the type that splice into a wire without cutting, should never be used on wiring used for an input to or output from a CPU.

## INFORMATION SHEET

- D. CPU system wiring has sealed terminal ends and connectors to keep moisture from corroding the contact area of the terminal. (Figure 2)

FIGURE 2



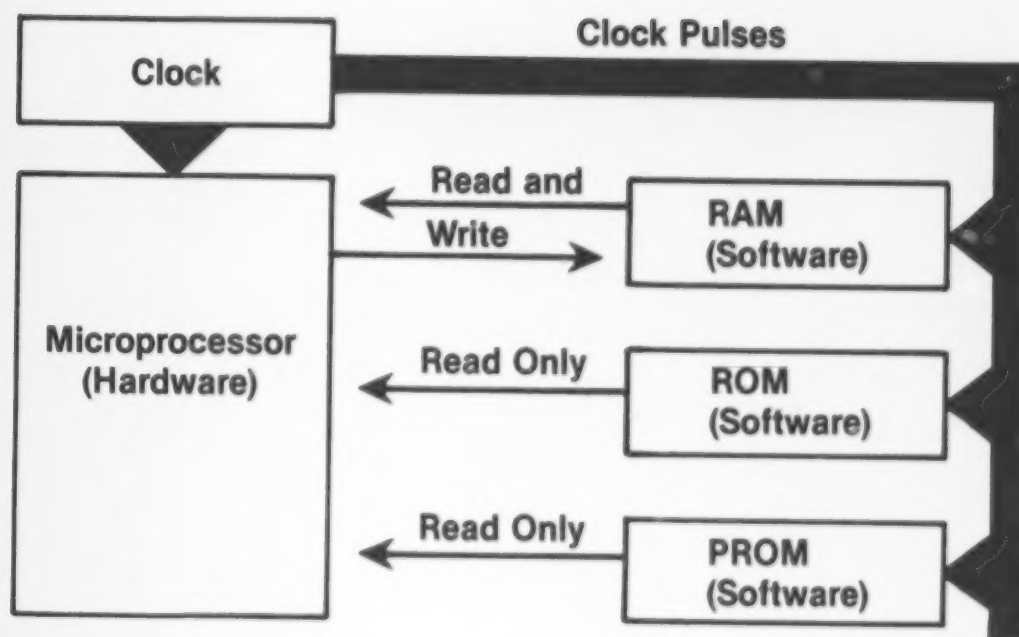
Courtesy Chevrolet Division, General Motors Corporation

- E. Take care when removing the terminals from the connector so that the lock tabs and ends are not damaged.
- F. For connector and terminal access, always refer to the service manual for the specific vehicle you are working on.

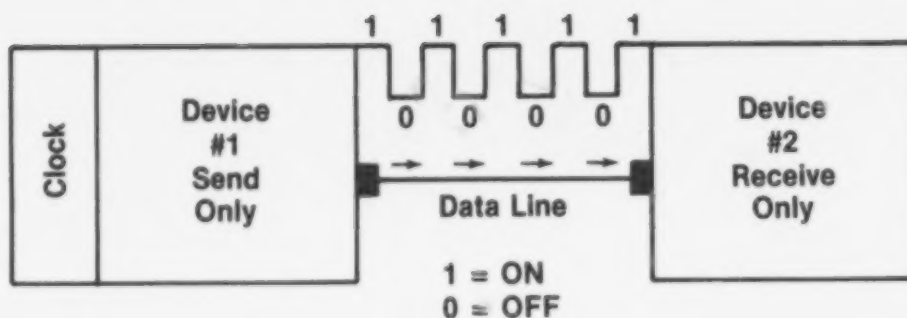
### XII. Microprocessor applications in automotive electronics

- A. CPUs were first installed in vehicles to control emissions, and to improve fuel economy in order to comply with government requirements.
- B. Since its first use in vehicles, the automotive computer, or CPU, has undergone many design changes which have made it:
1. Faster.
  2. More compact.
  3. More reliable.
  4. More versatile.
- C. Diagnosing problems with a CPU is accomplished with a process of elimination; everything in the sensor circuit is tested, encoder function is verified, and if no problem is found, the CPU is considered faulty.

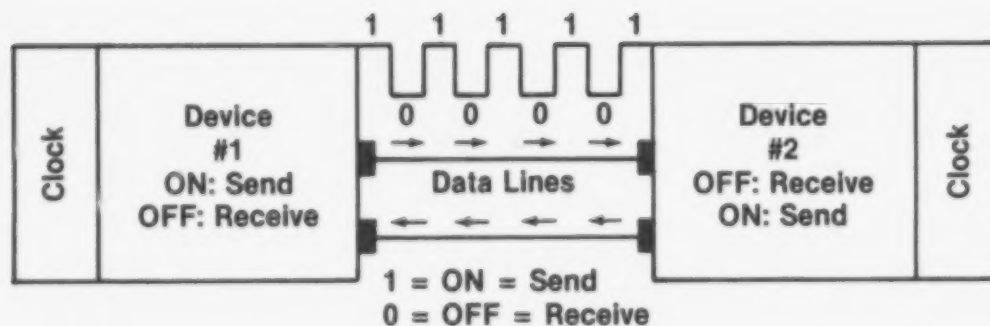
# CPU Architecture



# Serial and Duplex Serial Communications

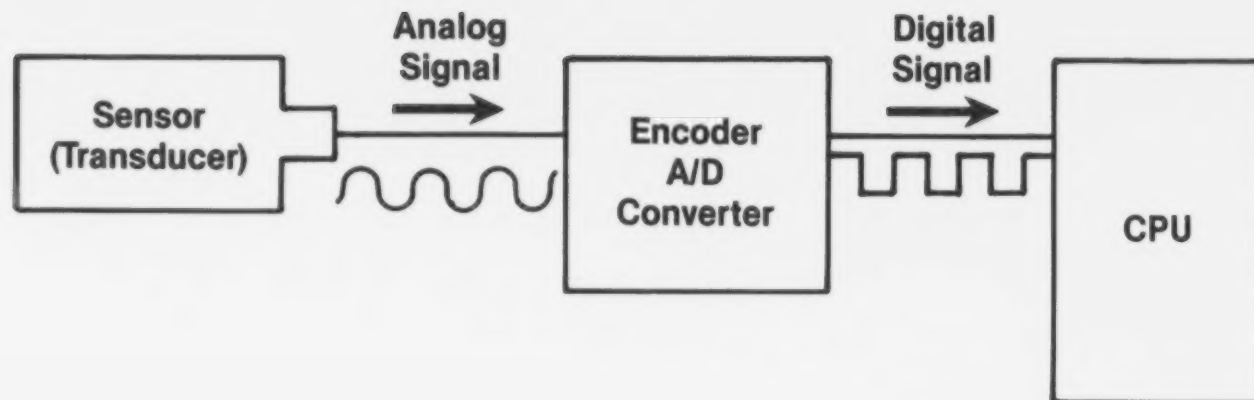


**Serial**



**Duplex Serial**

## Encoder and A/D Converter



## **AUTOMOTIVE MICROPROCESSORS UNIT VI**

### **JOB SHEET #1 — REMOVE AND REPLACE A PROM USING PROPER GROUNDING PROTECTION**

#### **A. Tools and materials**

1. Vehicle as selected by instructor
2. Appropriate service manual
3. Basic hand tools
4. Chip extractor
5. Ground clip
6. Fender covers
7. Safety glasses

#### **B. Procedure**

1. Bring the vehicle into the shop, open the hood, and install fender covers.
2. Put on safety glasses, block wheels, and install safety exhaust.
3. Remove the negative battery cable.
4. Open your service manual to the section that covers CPU removal.
5. Install a ground clip so that the alligator clip end is on a good, clean metal body part.
6. Install the other end of the ground clip to your belt, a pocket, or somewhere on your clothing.

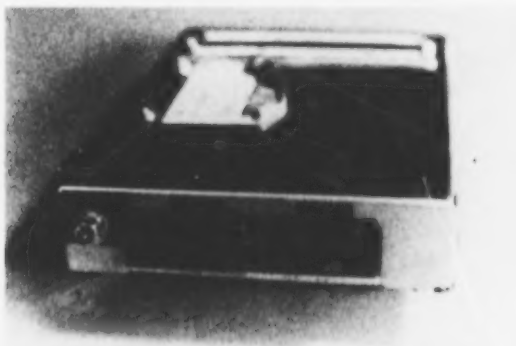


**JOB SHEET #1**

7. Remove the ECM. (Figure 1)

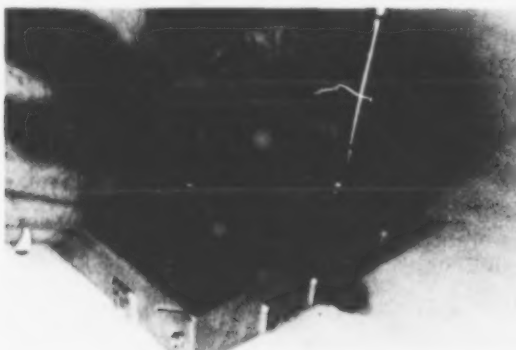
(NOTE: Because you are wearing a ground clip, the CPU components will be safe from voltage spikes that could damage them.)

FIGURE 1



8. Take the ECM to a workbench, and remove the PROM cover, if it can be removed. (Figure 2)

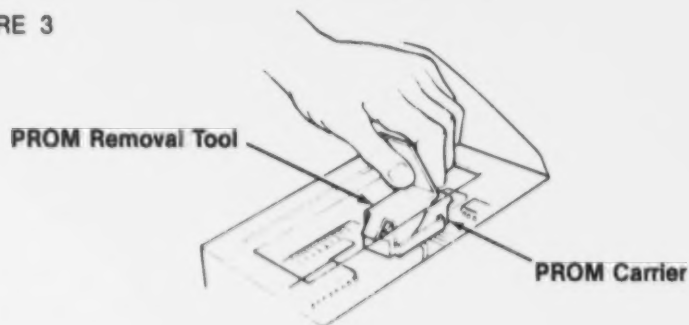
FIGURE 2



## JOB SHEET #1

9. Use the correct tool as shown in the service manual to remove the PROM, and then remove the PROM with the carrier. (Figure 3)

FIGURE 3



Courtesy Chevrolet Division, General Motors Corporation

10. Remove the PROM from its retainer, if the PROM can be removed, but be careful not to bend the terminal pins. (Figure 4)

FIGURE 4



☐ Have your instructor check your work.

11. Replace the PROM, and reinstall the CPU in the vehicle.

**(CAUTION: If the PROM is reinstalled backwards, it will be destroyed when the ignition is turned on.)**

12. Connect the negative battery cable, and start the vehicle to verify proper operation.
13. Turn ignition off, and return tools and materials to proper storage.

## **AUTOMOTIVE MICROPROCESSORS UNIT VI**

### **JOB SHEET #2 — TEST INTEGRITY OF GROUND AND POWER CIRCUITS**

#### **A. Tools and materials**

1. Vehicle as selected by instructor
2. Appropriate service manual
3. Basic hand tools
4. DVOM (high impedance)
5. Fender covers
6. Safety glasses

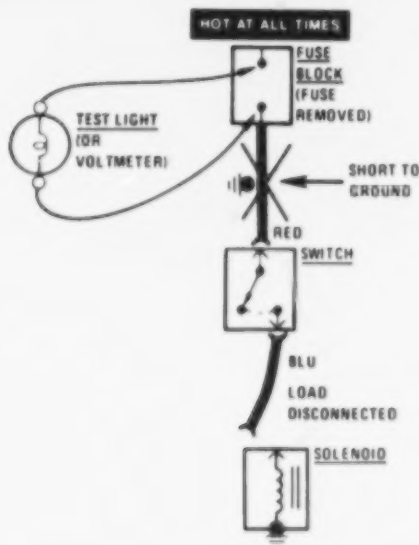
#### **B. Procedure**

1. Bring vehicle into shop, open hood, and install fender covers.
2. Put on safety glasses, block wheels, and install safety exhaust.
3. Open your service manual to the section that covers power distribution and ground locations.
4. Ask your instructor to indicate the circuits that have been disabled for the purposes of this job sheet.
5. Locate and remove the blown circuit fuse.
6. Disconnect the load.

## JOB SHEET #2

7. Check to make sure the fuse is powered, and then connect the DVOM leads or test light leads across the fuse terminals. (Figure 1)

FIGURE 1



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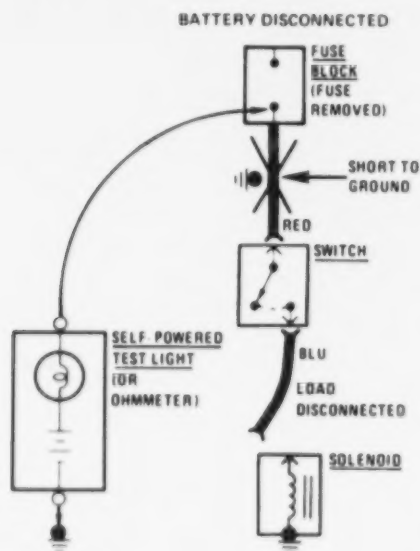
8. Start near the fuse box, keep your eye on your DVOM or test light, and wiggle the wiring harness from side to side.
9. Keep wiggling the wiring harness from side to side at intervals of about 6 inches while you keep your eyes on the DVOM or the light.
10. Watch for the test light to flicker or the DVOM to register a reading, and when it does, it means there is a short to ground in the wiring at the point where you last wiggled the harness.
 

☐ Have your instructor check your work.
11. Move on to the next disabled circuit, remove the blown fuse, and disconnect the battery and the load.

## JOB SHEET #2

12. Connect one lead of your DVOM or a self-powered test light to the load side of the fuse terminal. (Figure 2)

FIGURE 2



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13. Connect the other lead to a known good ground.
14. Repeat the process of wiggling the wiring harness at 6 inch intervals.
15. Watch for the DVOM to register or the test light to glow, and this will indicate a short to ground in the wiring at the point you last wiggled the harness.
16. Clean area, secure vehicle, and return tools to proper storage.

## AUTOMOTIVE MICROPROCESSORS UNIT VI

### JOB SHEET #3 — REPAIR CONNECTOR TERMINALS

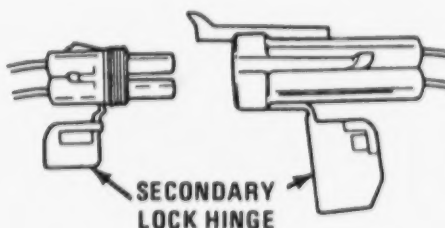
#### A. Tools and materials

1. Vehicle as selected by instructor
2. Appropriate service manual
3. Basic hand tools
4. Wire repair kit with terminal removing tools
5. Soldering pencil
6. Fender covers
7. Safety glasses

#### B. Procedure

1. Bring vehicle into shop, open hood, and install fender covers.
2. Put on safety glasses, block wheels, and install safety exhaust.
3. Locate the connector your instructor has selected to be repaired.
4. Open your service manual to the electrical section that illustrates how to remove the lock tabs of the connector, and how to remove the terminal end.
5. Open the secondary lock hinge on the connector. (Figure 1)

FIGURE 1

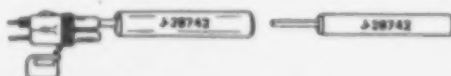


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## JOB SHEET #3

6. Remove the terminals with the terminal removal tool. (Figure 2)

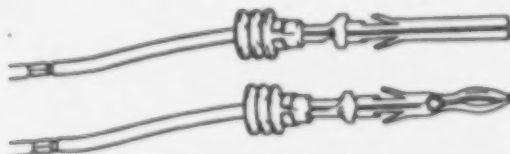
FIGURE 2



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7. Cut the wire, crimp on a new weatherproof lead assembly, and solder it with rosin core solder. (Figure 3)

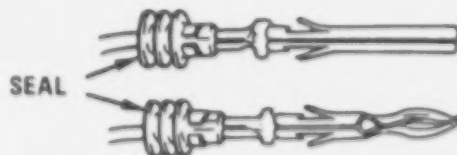
FIGURE 3



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8. Cut the wire just behind the cable seal if lead assemblies are not available, slip a new cable seal on the wire, strip about  $\frac{3}{16}$ " of insulation from the wire, and position the seal as indicated. (Figure 4)

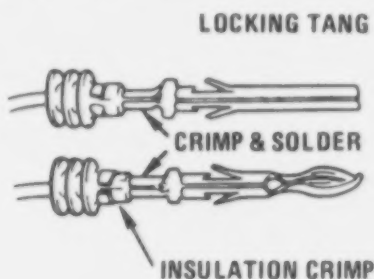
FIGURE 4



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**JOB SHEET #3**

9. Use a crimping tool to crimp the new terminal onto the wire, solder as specified, and crimp the insulation as indicated. (Figure 5)

**FIGURE 5**

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10. Allow the terminal to cool.
11. Reinstall the terminal end in the connector, and secure the connector locking device.
- ☐ Have your instructor check your work.
12. Reconnect wiring to its original location.
13. Start the engine, and verify proper operation.
14. Turn ignition off, remove fender covers, and close hood.
15. Return tools and materials to proper storage.



## AUTOMOTIVE MICROPROCESSORS UNIT VI

### PRACTICAL TEST #1 JOB SHEET #1 — REMOVE AND REPLACE A PROM USING PROPER GROUNDING PROTECTION

Student's name \_\_\_\_\_

Date \_\_\_\_\_

Evaluator's name \_\_\_\_\_

Attempt no. \_\_\_\_\_

Student instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

#### PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:

|                                             | YES                         | NO                       |
|---------------------------------------------|-----------------------------|--------------------------|
| 1. Wore safety glasses.                     | 1. <input type="checkbox"/> | <input type="checkbox"/> |
| 2. Prepared vehicle safely.                 | 2. <input type="checkbox"/> | <input type="checkbox"/> |
| 3. Installed ground clip properly.          | 3. <input type="checkbox"/> | <input type="checkbox"/> |
| 4. Removed CPU properly.                    | 4. <input type="checkbox"/> | <input type="checkbox"/> |
| 5. Removed PROM with no pin damage.         | 5. <input type="checkbox"/> | <input type="checkbox"/> |
| 6. Replaced PROM properly.                  | 6. <input type="checkbox"/> | <input type="checkbox"/> |
| 7. Reinstalled CPU properly.                | 7. <input type="checkbox"/> | <input type="checkbox"/> |
| 8. Verified engine operation.               | 8. <input type="checkbox"/> | <input type="checkbox"/> |
| 9. Returned tools and materials to storage. | 9. <input type="checkbox"/> | <input type="checkbox"/> |

Evaluator's comments: \_\_\_\_\_

 \_\_\_\_\_  
 \_\_\_\_\_

## JOB SHEET #1 PRACTICAL TEST

### PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another test procedure must be submitted for evaluation.)

Criteria:

|                        |                           |                          |                                  |               |
|------------------------|---------------------------|--------------------------|----------------------------------|---------------|
| Tool and Equipment Use | Excellent<br>4            | Good<br>3                | Fair<br>2                        | Poor<br>1     |
| Work Pace              | Timely<br>4               | Acceptable<br>3          | Slow<br>2                        | Too Slow<br>1 |
| Procedure              | Complete and Correct<br>4 | Acceptable<br>3          | Incomplete and/or Incorrect<br>2 | Improper<br>1 |
| Safety                 | Well Observed<br>4        | Acceptably Observed<br>3 | Improperly Observed<br>2         | Careless<br>1 |

EVALUATOR'S COMMENTS: \_\_\_\_\_

#### PERFORMANCE EVALUATION KEY

- 4 — Skilled — Can perform job with no additional training.
- 3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
- 2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
- 1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

## AUTOMOTIVE MICROPROCESSORS UNIT VI

### PRACTICAL TEST #2 JOB SHEET #2 — TEST INTEGRITY OF GROUND AND POWER CIRCUITS

Student's name \_\_\_\_\_

Date \_\_\_\_\_

Evaluator's name \_\_\_\_\_

Attempt no. \_\_\_\_\_

Student instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

#### PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

| The student:                                | YES                         | NO                       |
|---------------------------------------------|-----------------------------|--------------------------|
| 1. Wore safety glasses.                     | 1. <input type="checkbox"/> | <input type="checkbox"/> |
| 2. Prepared vehicle safely.                 | 2. <input type="checkbox"/> | <input type="checkbox"/> |
| 3. Referenced service manual properly.      | 3. <input type="checkbox"/> | <input type="checkbox"/> |
| 4. Set up DVOM to read volts.               | 4. <input type="checkbox"/> | <input type="checkbox"/> |
| 5. Made wiggle test to find short.          | 5. <input type="checkbox"/> | <input type="checkbox"/> |
| 6. Set up DVOM to read ohms.                | 6. <input type="checkbox"/> | <input type="checkbox"/> |
| 7. Made wiggle test to find short.          | 7. <input type="checkbox"/> | <input type="checkbox"/> |
| 8. Verified engine operation.               | 8. <input type="checkbox"/> | <input type="checkbox"/> |
| 9. Returned tools and materials to storage. | 9. <input type="checkbox"/> | <input type="checkbox"/> |

Evaluator's comments: \_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

## JOB SHEET #2 PRACTICAL TEST

### PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another test procedure must be submitted for evaluation.)

Criteria:

|                        |                           |                          |                                  |               |
|------------------------|---------------------------|--------------------------|----------------------------------|---------------|
| Tool and Equipment Use | Excellent<br>4            | Good<br>3                | Fair<br>2                        | Poor<br>1     |
| Work Pace              | Timely<br>4               | Acceptable<br>3          | Slow<br>2                        | Too Slow<br>1 |
| Procedure              | Complete and Correct<br>4 | Acceptable<br>3          | Incomplete and/or Incorrect<br>2 | Improper<br>1 |
| Safety                 | Well Observed<br>4        | Acceptably Observed<br>3 | Improperly Observed<br>2         | Careless<br>1 |

EVALUATOR'S COMMENTS: \_\_\_\_\_

#### PERFORMANCE EVALUATION KEY

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- 2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
- 1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

## AUTOMOTIVE MICROPROCESSORS UNIT VI

### PRACTICAL TEST #3 JOB SHEET #3 — REPAIR CONNECTOR TERMINALS

Student's name \_\_\_\_\_

Date \_\_\_\_\_

Evaluator's name \_\_\_\_\_

Attempt no. \_\_\_\_\_

Student instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

#### PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:

YES

NO

1. Wore safety glasses.
2. Prepared vehicle safely.
3. Referenced service manual properly.
4. Removed connector lock tabs properly.
5. Cut and stripped wire properly.
6. Soldered wire to specifications.
7. Reinstalled connector.
8. Verified engine operation.
9. Returned tools and materials to storage.

|    |                          |                          |
|----|--------------------------|--------------------------|
| 1. | <input type="checkbox"/> | <input type="checkbox"/> |
| 2. | <input type="checkbox"/> | <input type="checkbox"/> |
| 3. | <input type="checkbox"/> | <input type="checkbox"/> |
| 4. | <input type="checkbox"/> | <input type="checkbox"/> |
| 5. | <input type="checkbox"/> | <input type="checkbox"/> |
| 6. | <input type="checkbox"/> | <input type="checkbox"/> |
| 7. | <input type="checkbox"/> | <input type="checkbox"/> |
| 8. | <input type="checkbox"/> | <input type="checkbox"/> |
| 9. | <input type="checkbox"/> | <input type="checkbox"/> |

Evaluator's comments: \_\_\_\_\_

 \_\_\_\_\_  
 \_\_\_\_\_

## JOB SHEET #3 PRACTICAL TEST

### PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another test procedure must be submitted for evaluation.)

Criteria: \_\_\_\_\_

|                        |                           |                          |                                  |               |
|------------------------|---------------------------|--------------------------|----------------------------------|---------------|
| Tool and Equipment Use | Excellent<br>4            | Good<br>3                | Fair<br>2                        | Poor<br>1     |
| Work Pace              | Timely<br>4               | Acceptable<br>3          | Slow<br>2                        | Too Slow<br>1 |
| Procedure              | Complete and Correct<br>4 | Acceptable<br>3          | Incomplete and/or Incorrect<br>2 | Improper<br>1 |
| Safety                 | Well Observed<br>4        | Acceptably Observed<br>3 | Improperly Observed<br>2         | Careless<br>1 |

EVALUATOR'S COMMENTS: \_\_\_\_\_

#### PERFORMANCE EVALUATION KEY

- 4 — Skilled — Can perform job with no additional training.
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- 2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
- 1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

## AUTOMOTIVE MICROPROCESSORS UNIT VI

### TEST

NAME \_\_\_\_\_

SCORE \_\_\_\_\_

1. Match terms related to automotive microprocessors with their correct definitions.

- |                                                                                                                                                   |                       |
|---------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------|
| _____a. The measurement of the speed of data transmission along a communication link                                                              | 1. Burning            |
| _____b. A process that etches certain predesigned circuits into a microcomputer chip                                                              | 2. Software           |
| _____c. Mechanical data links for transmission of data from various components in a computer system                                               | 3. Duplex serial data |
| _____d. The brains of a microcomputer where comparisons are made and command decisions executed                                                   | 4. Transducer         |
| _____e. Bi-directional data transmission that uses a clock pulse to determine whether a device is sending or receiving data on a shared data line | 5. BAUD rate          |
| _____f. The physical components of a computer system                                                                                              | 6. Serial data        |
| _____g. Data transmission that sends one bit of information at a time in a sequential order                                                       | 7. Busses             |
| _____h. the programs or compilers that address the computer memory required to perform a desired function                                         | 8. CPU                |
| _____i. A device that changes one form of energy into another form of energy                                                                      | 9. Hardware           |

2. Complete statements concerning computer hardware/software by circling the word(s) that best complete(s) each statement.

- a. The CPU is the (**brawn, brains**) of a computer; it retrieves information to be processed, processes that information, performs functions, and stores information.
- b. As the name implies, ROM can be read from but not written to. It is a form of memory that can be used to store information only once, and is considered (**software, hardware**).



## TEST

- c. RAM is a computer's (**usable, standby**) memory that can be read from and written to, and is the location where calculations and comparisons are stored for use.
  - d. The (**ROM, PROM**) chip is valuable because it can have a variety of data parameters burned into its circuitry and be updated and changed to correct system problems.
  - e. PROM data cannot be changed but an (**ERAM, EPROM**) can be erased and reprogrammed.
  - f. An EPROM is usually erased with a(n) (**fiber optics, ultraviolet light**), but burning PROMs or EPROMs requires sophisticated equipment.
3. Select true statements concerning the computer as a decision center by placing an "X" beside each statement that is true.
- \_\_\_\_\_a. A computer works on a binary base 2 numbering system, and that means all data represents a YES/NO, ON/OFF condition that the computer uses to make decisions.
  - \_\_\_\_\_b. Some computers working with artificial intelligence can reason, but an automotive computer can only calculate.
  - \_\_\_\_\_c. The major advantage of a computer is that it performs ON/OFF, YES/NO decision making with remarkable speed.
4. Solve problems concerning how a computer handles input/output by answering the following questions.
- a. If input to a computer is inaccurate, then the output will be inaccurate, and this is better known as what?  
 Answer: \_\_\_\_\_
  - b. In the automotive field, trouble codes tell a technician that the input/output data processed failed to do what?  
 Answer: \_\_\_\_\_  
 \_\_\_\_\_
5. Select true statements concerning guidelines for handling computers by placing an "X" beside each statement that is true.
- (NOTE: For a statement to be true, all parts of the statement must be true.)
- \_\_\_\_\_a. DON'T connect or disconnect any CPU components when the IGNITION KEY IS ON.



## TEST

- \_\_\_\_\_b. DON'T connect or disconnect the CPU harness when the IGNITION KEY IS ON.
  - \_\_\_\_\_c. DO leave the IGNITION KEY ON when working with microprocessors in:
    - 1) Electronic climate control modules.
    - 2) Electronic instrument cluster modules.
    - 3) Cruise control modules.
    - 4) Vehicle level ride control modules
  - \_\_\_\_\_d. DO test a CPU controlled switch or sensor with a 12-volt source because some sensors require a constant 12-volt power supply.
  - \_\_\_\_\_e. When removing the CPU assembly from a vehicle, DO ground yourself with a ground clip with one end attached to your clothes, and the other end attached to the negative post of the battery or a chassis ground.
  - \_\_\_\_\_f. When working with a CPU on a workbench, DO ground yourself properly with a ground clip attached to your clothes, and the other end attached to a proper ground.
6. Select true statements concerning automotive microprocessor architecture by placing an "X" beside each statement that is true.

(NOTE: For a statement to be true, all parts of the statement must be true.

- \_\_\_\_\_a. All CPUs have certain components in common:
  - 1) RAM
  - 2) ROM
  - 3) PROM
  - 4) Microprocessor
- \_\_\_\_\_b. RAM is the only part of a computer which can be replaced.
- \_\_\_\_\_c. ROM is filled with data that is used for internal control of computer operations.
- \_\_\_\_\_d. PROM is generally a permanent component.
- \_\_\_\_\_e. PROM is a section of memory that contains specific information about the engine fuel system, transmission, rear axle, emission system, and vehicle options.

## TEST

- \_\_\_\_f. The CPU is the brains of the computer, and controls the address buss, retrieval of information, calculations, and output commands to sensors.
  - \_\_\_\_g. The CPU also has a "board" with the harness connector receivers attached to the end of the board to provide a tight connection between the sensors and the CPU.
  - \_\_\_\_h. On fuel injected engines, most CPUs contain an additional PROM which contains the back-up fuel programs that keep the engine operating in case of total system failure.
  - \_\_\_\_i. Another important CPU function is handling the full system voltage circuits by grounding the circuits to turn them ON/OFF.
  - \_\_\_\_j. The CPU component that handles the higher voltage circuits is called a "Quad Driver," and there are usually three or four of these grounding devices in a CPU.
  - \_\_\_\_k. Quad drivers are tested by measuring for a minimum resistance of 50,000 ohms between the quad driver terminal and the ECM case.
7. Complete statements concerning serial and duplex serial communications by circling the word(s) that best complete(s) each statement.
- a. Some (**advanced, older**) CPU systems incorporate a BCM to manage support systems such as the ECC, electronic instrument panel, and fuel data readout.
  - b. Some vehicles use a (**parallel, serial**) data link between various computerized control modules, including the CPU, BCM, instrument panel, power module, ECC, and programmer.
  - c. In some systems, the CPU and the BCM use (**duplex serial, system**) data to communicate back and forth.
  - d. Duplex serial data transmission is (**uni-directional, bi-directional**), and uses one data line for both sending and receiving information.
  - e. Each device on the ends of a duplex serial data line can (**transmit and receive data, transmit only**).
  - f. The clock high voltage ON signal tells device one to send and device two to receive; the clock low voltage (**OFF, ON**) signal tells device one to receive, and device two to send.
8. Complete statements concerning other data communication techniques by circling the word(s) that best complete(s) each statement.
- a. Duplex serial communications have (**limited, many**) applications, but UART communications link have even more advanced applications.

## TEST

- b. The UART system sends a complicated duplex serial data stream that requires a system of **(protocol, priorities)**.
  - c. **(Protocol, Priority)** means that each word position in a data stream corresponds to the same data parameter each time the data stream is transmitted.
  - d. Each device in the UART data link has a **(polling, parameter)** code, and when the BCM sends out that code, the device transmits its data.
  - e. The UART system uses a 64-word data stream, and each device reads only the **(data words, polling codes)** that it needs to respond to.
9. Solve problems concerning parallel data communications by answering the following questions.
- a. Since parallel data communications require a wire for every data bit in a computer, how does this limit their automotive applications?  
Answer: \_\_\_\_\_
  - b. In what car line would you find a parallel data link?  
Answer: \_\_\_\_\_
10. Complete statements concerning transducers and encoders by circling the word(s) that best complete(s) each statement.
- a. Almost all automotive sensors are **(transmitters, transducers)** in that they change other energy forms into electricity.
  - b. The electricity from sensors is in an **(analog, digital)** form, and must be converted into a **(digital, analog)** form before the CPU can process the information.
  - c. Conversion of analog signals to digital signals is accomplished by devices called **(“encoders”, “converters”)**.
  - d. **(Encoders, Converters)** not only convert analog signals to digital signals, they “chop” digital data into binary bits of information for storage and manipulation by the CPU.
  - e. **(Encoders, Converts)** are internal components of a computer, and cannot be serviced separately.

## TEST

11. Select true statements concerning Weather Pack® connectors and locks by placing an "X" beside each statement that is true.
- \_\_\_\_\_a. To withstand voltage spikes, shocks, and vibrations that an automotive CPU is subjected to, the modules are encased in special weatherproof materials, and have locks designed to assure tight connections for sensor inputs.
  - \_\_\_\_\_b. Corrosion on a terminal can raise the resistance of a circuit, and even a slight resistance increase can cause a voltage drop of a few millivolts, and affect the operation of the engine.
  - \_\_\_\_\_c. Crimp type connectors, or the type that splice into a wire without cutting, should always be used on wiring used for an input to or output from a CPU.
  - \_\_\_\_\_d. CPU system wiring has sealed terminal ends and connectors to keep moisture from corroding the contact area of the terminal.
  - \_\_\_\_\_e. Take care when removing the terminals from the connector so that the lock tabs and ends are not damaged.
  - \_\_\_\_\_f. For connector and terminal access, always refer to the service manual for the specific vehicle you are working on.
12. Complete statements concerning microprocessor applications in automotive electronics by circling the word(s) that best complete(s) each statement.
- a. CPUs were first installed in vehicles to control (**speed, emissions**), and to improve fuel economy in order to comply with government regulations.
  - b. Since its first use in vehicles, the automotive computer, or CPU, has undergone many design changes which have made it:
    - 1) (**Heavier, Faster**)
    - 2) (**Larger, More compact**)
    - 3) (**More reliable, Less reliable**)
    - 4) (**More versatile, Limited but powerful**)
  - c. Diagnosing problems with a CPU is accomplished with a process of (**intelligent guessing, elimination**); everything in the sensor circuit is tested, encoder function is verified, and if no problem is found, the CPU is considered faulty.
13. Demonstrate the ability to:
- a. Remove and replace a PROM using proper grounding protection. (Job Sheet #1)
  - b. Test integrity of ground and power circuits. (Job Sheet #2)
  - c. Repair connector terminals. (Job Sheet #3)

## AUTOMOTIVE MICROPROCESSORS UNIT VI

### ANSWERS TO TEST

1.   a.   5                   d.   8                   g.   6  
     b.   1                   e.   3                   h.   2  
     c.   7                   f.   9                   i.   4
  
2.   a.   Brains  
     b.   Software  
     c.   Usable  
     d.   PROM  
     e.   EPROM  
     f.   Ultraviolet light
  
3.   a, c
  
4.   a.   Garbage in, garbage out  
     b.   Meet allowable parameters stored in memory
  
5.   a, b, e, f
  
6.   a, c, e, f, g, h, i, j, k
  
7.   a.   Advanced  
     b.   Serial  
     c.   Duplex serial  
     d.   Bi-directional  
     e.   Transmit and receive data  
     f.   OFF
  
8.   a.   Many  
     b.   Protocol  
     c.   Protocol  
     d.   Polling  
     e.   Data words
  
9.   a.   Their applications are limited  
     b.   The GM 30 car line

## ANSWERS TO TEST

- 10.
  - a. Transducers
  - b. Analog, digital
  - c. Encoders
  - d. Encoders
  - e. Encoders
  
- 11. a, b, d, e, f
  
- 12.
  - a. Emissions
  - b.
    - 1) Faster
    - 2) More compact
    - 3) More reliable
    - 4) More versatile
  - c. Elimination
  
- 13. Job sheets evaluated according to criteria in practical tests



## COMPUTERIZED ENGINE CONTROLS UNIT VII

### UNIT OBJECTIVE

After completion of this unit, the student should be able to discuss sensors common to computerized engine controls, and define sensor interaction. The student should also be able to relate other sensors to their specific functions, and test, diagnose, and service sensor problems. These competencies will be evidenced by correctly completing the procedures outlined in the job sheets, and by scoring a minimum of 85 percent on the unit test.

### SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms related to computerized engine controls with their correct definitions.
2. Select true statements concerning O<sub>2</sub> (Oxygen) sensors.
3. Solve problems concerning O<sub>2</sub> sensor operating requirements.
4. Complete statements concerning MAP (Manifold Absolute Pressure) sensors
5. Solve problems concerning coolant temperature sensors.
6. Complete statements concerning engine RPM inputs to the CPU.
7. Select true statements concerning crankshaft position sensors.
8. Solve problems concerning the TPS (Throttle Position Sensor).
9. Select true statements concerning MAT (Manifold Air Temperature) sensors.
10. Complete statements concerning MAF (mass-air flow) sensors.
11. Solve problems concerning input sensor interaction.
12. Complete statements concerning system output controls.
13. Solve problems concerning pulse width and on time functions.
14. Select true statements concerning fuel control systems.
15. Solve problems concerning ignition spark timing control.

**OBJECTIVE SHEET**

16. Select true statements concerning EGR (Exhaust Gas Recirculation) controls.
17. Complete statements concerning emission control devices.
18. Demonstrate the ability to:
  - a. Test oxygen sensor operations. (Job Sheet #1)
  - b. Test MAP sensor operations. (Job Sheet #2)
  - c. Test engine coolant temperature sensor operations. (Job Sheet #3)
  - d. Test TPS operations. (Job Sheet #4)
  - e. Test EGR valve operations. (Job Sheet #5)
  - f. Adjust ignition timing. (Job Sheet #6)



## COMPUTERIZED ENGINE CONTROLS UNIT VII

### SUGGESTED ACTIVITIES

- A. Provide students with objective sheet.
- B. Provide students with information sheet.
- C. Make transparencies.
- D. Discuss unit and specific objectives.
- E. Discuss information sheet.
- F. Discuss and demonstrate the procedures outlined in the job sheets.
- G. Arrange for vehicles and appropriate service manuals so job sheets will reflect real-world troubleshooting.
- H. Use an oscilloscope to demonstrate to students the different sensor outputs, including O<sub>2</sub>, MAP, MAF, TPS, Knock, and others as available.
- I. Give test.

### REFERENCES USED IN DEVELOPING THIS UNIT

- A. *EEC III EEC IV 5-DAY TECHNICIAN CERTIFICATION*. Dearborn, MI 48121: Ford Parts and Service Division, Training and Publications Department, 1985.
- B. *Electricity and Electronics, Fundamentals*. Highland Park, MI 48203: Service Training, Chrysler Corporation, 1984.
- C. *Servicing Vehicle Electronic Instruments*. Dearborn, MI 48121: Ford Parts and Service Division, Training and Publications Department, 1985.
- D. *Specialized Electronics Training*. Warren, MI 48090: Product Service Training, General Motors Corporation, 1984.
- E. *Tools and Techniques, Chrysler Computerized Engine Controls Through 1985*. Owatona, MN 55060: Mitchell Information Services, Inc., 1985.
- F. *Tools and Techniques, Ford MCU and EEC-IV, Computerized Engine Controls Through 1985*. Owatona, MN 55060: Mitchell Information Services, Inc., 1985.
- G. *Tools and Techniques, General Motors Computerized Engine Controls Through 1985*. Owatona, MN 55060: Mitchell Information Services, Inc., 1985.

## COMPUTERIZED ENGINE CONTROLS UNIT VII

### INFORMATION SHEET

#### I. Terms and definitions

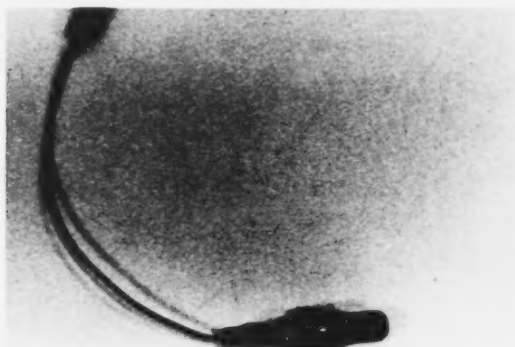
- A. CPU (Central Processing Unit) — A computer that receives inputs from various sensors, and compares them with predetermined values in order to command required engine controls
- B. Engine sensors — Devices that tell the CPU about engine operating conditions at a given moment
- C. Vehicle sensors — Devices that tell the CPU about non-engine operating conditions such as vehicle speed and passenger compartment temperature
- D. PROM (Programmable Read Only Memory) — A silicon chip that has stored on it the parameters for such specific applications as timing and fuel delivery for a cold engine with half throttle opening
- E. Open loop operations — The first operating mode after start-up when engine operations are being controlled by specific parameters in PROM
- F. Closed loop operation — An operating mode where all sensors are operational, and engine operations are controlled by constant CPU updates to engine parameters such as air:fuel ratio, timing, and emission control devices
- G. Parameter — A scale defining the maximum and minimum limit that a value must have to meet a standard
- H. CPU warning light — A light on the drive information panel that warns of a system problem with one or more sensor inputs
- I. Direct relationship — A condition in which the increase of one parameter will cause an increase in a related parameter
- J. Inverse relationship — A condition in which the increase of one parameter will cause a decrease in a related parameter
- K. Base timing — Timing mechanically set without CPU interference
- L. Pulse width — The unit of measurement used by the CPU to control fuel output; it is based on 10 cycles per second, and the ON time of each cycle is controlled by the CPU
- M. NO<sub>x</sub> — Oxides of nitrogen that are part of exhaust emissions that must be minimal to meet EPA standards

## INFORMATION SHEET

### II. O<sub>2</sub> (oxygen) sensors

- A. The oxygen sensor is located in the exhaust system near the engine, and measures the amount of oxygen content in the exhaust.
- B. The oxygen sensor is a lambda sensor with a zirconium electrolyte between two platinum plates with one plate exposed to the exhaust system, and the other plate exposed to the atmosphere. (Figure 1)

FIGURE 1



- C. When the air:fuel ratio is lean (less fuel, more air), the exhaust stream contains more oxygen, and when the air:fuel ratio is rich, the exhaust stream contains less oxygen.

Example: A lean mixture has a higher fuel to air ratio than the 14.7:1 median, and a rich mixture has a lower fuel to air ratio than 14.7:1, so 15.5:1 would be a lean mixture, and 13:1 would be a rich mixture.

- D. The oxygen sensor creates a voltage of between .2 and 1.0 volts by electron transfer in the zirconium electrolyte between the platinum plates.
- E. If the air:fuel ratio is lean, the oxygen sensor will generate a lower voltage, and if the air:fuel ratio is rich, the oxygen sensor will generate a higher voltage.
- F. Oxygen sensor/CPU interaction is continuous:
  1. The CPU sends a .45 volt signal to the oxygen sensor at all times.
  2. When the sensor is generating a low voltage (below 4.5v), the sensor drains some of the CPU signal, and brings the CPU signal down.
  3. When the sensor is generating a high voltage (above 4.5v), the sensor adds to the CPU signal, and makes the CPU signal higher.

## INFORMATION SHEET

- G. The raising and lowering of the signal voltage across the .45v reference signal creates "cross-counts" which indicate sensor activity.
- H. A normal oxygen sensor should show approximately 5 to 8 cross-counts per second at engine idle.
- I. Troubleshooting an oxygen sensor requires a digital voltmeter with a minimum of 10 megohms impedance, because using a standard voltmeter will produce highly inaccurate readings.

(NOTE: Oxygen sensors output an analog signal which is converted to a digital signal by the CPU.)

### III. O<sub>2</sub> sensor operating requirements

- A. The O<sub>2</sub> sensor must be warmed up and operating at a minimum temperature of 600°F in order for the CPU to go into closed loop operation.
- B. Some O<sub>2</sub> sensors have electric internal heaters to help them maintain operating temperature.
- C. If the O<sub>2</sub> sensor is contaminated, it will not warm up, but instead will cause the CPU to stay in open loop, and this directly affects engine operation.
- D. A physically damaged O<sub>2</sub> sensor will not operate properly, and can cause a CPU to stay in open loop.

### IV. MAP (Manifold Absolute Pressure) sensors (Figure 2)

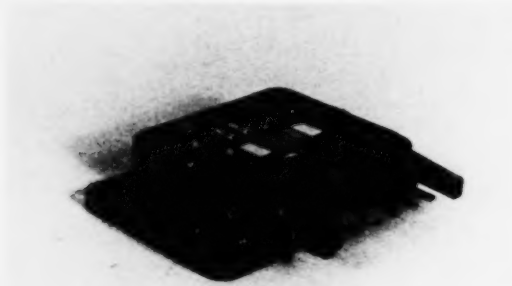
- A. Engines require different amounts of fuel for different "load" conditions.  
 EXAMPLE: Driving up a long, steep hill would require much more fuel than driving along at 55 mph on a level freeway.
- B. The engine parameter that indicates the amount of load on the engine is manifold vacuum:
  - 1. At WOT (wide open throttle), the manifold vacuum is at it lowest, or zero inches of Mercury at sea level.
  - 2. During deceleration, manifold vacuum is at its highest level which is usually around 22 inches of Mercury at sea level.
- C. Vacuum produced by an engine at higher altitudes is less because the air is thinner.
- D. Some vehicles use a barometric sensor to compensate for altitude change, and other combine the MAP and barometric sensors.

(NOTE: The principles for both systems are the same.)

## INFORMATION SHEET

- E. MAP sensor voltage output is inversely proportional to manifold vacuum, and as vacuum increases, voltage output decreases, so a high voltage reading would indicate WOT under heavy load, and a low voltage reading indicates normal throttle under minimum load. (Figure 2)

FIGURE 2

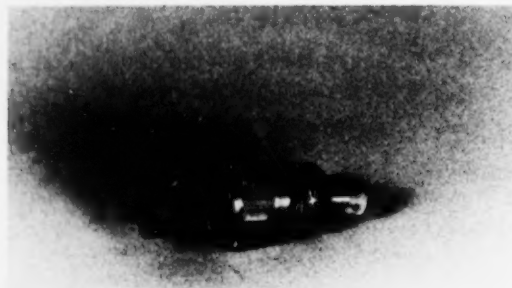


- F. The CPU receives MAP sensor analog inputs, combines them with other inputs into digital information, and determines the amount of fuel and timing required for engine load conditions.

### V. Coolant temperature sensors (Figure 3)

- A. The coolant system uses a sensor that operates as a thermistor; as temperature goes up, resistance increases.
- B. On fuel injected engines, the coolant sensor tells the CPU when the engine is cold and needs more fuel, and this function is similar to a choke on a carbureted engine.
- C. When an engine overheats, the coolant sensor input is used by the CPU to stop the air conditioner, and help the engine cool down. (Figure 3)

FIGURE 3



## INFORMATION SHEET

- D. On vehicles that use voice module systems to talk to the driver, the coolant sensor input triggers the overheating message that alerts the driver to the problem.
- E. Weak coolant can cause erroneous sensor readings because of corrosion that builds up on the sensor.
- F. A coolant/water mixture of 50%/50% is the most effective mixture for proper cooling; any less coolant might lead to corrosion problems, and any more coolant would be a waste of money.

### VI. Engine RPM inputs to the CPU

- A. The burn time of the air/fuel mixture in an engine is relatively constant, so as engine RPM increases, the timing must be advanced in order to completely burn increased combustion gases.
- B. The input from the distributor to the CPU is called "distributor reference pulse."
- C. Some computer systems use the CPU for all timing changes while other systems leave the centrifugal advance mechanism intact, but whatever the system, the CPU must know engine RPMs in order to command fuel/timing to meet engine requirements.
- D. Setting the base timing of the ignition system requires disabling CPU control of timing, and this is usually done by interrupting the distributor reference to the CPU.

(CAUTION: Interrupting CPU timing control requires careful attention to the procedure in the appropriate service manual.)

- E. The engine diagnostic code that identifies the distributor reference signal is essential to CPU diagnostics.
- F. Distributor signals may be analog or digital.

### VII. Crankshaft position sensors

- A. When an ignition system does not use a distributor, the CPU receives the engine RPM reference from a crankshaft position sensor.
- B. The "crank sensor" is a "hall effect" switch that outputs digital signals that are either ON or OFF.

(NOTE: Crank sensors are located at various points on the crankshaft, from the dampener to the flywheel.)



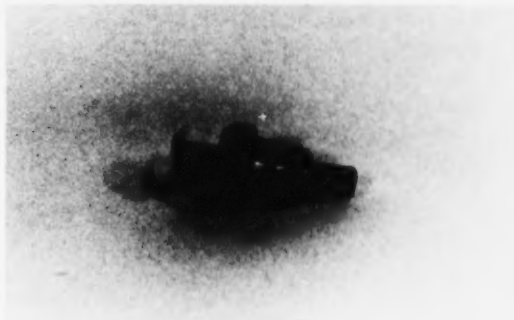
## INFORMATION SHEET

- C. In a four cycle engine, the crankshaft rotates twice for every single crankshaft rotation, and the CPU needs to know when the piston is coming up on a compression stroke or an exhaust stroke, and this is accomplished with a camshaft sensor.

(NOTE: Some crank and cam sensors are built into one unit, and others are separate units with inputs that the CPU coordinates for ignition.)

- D. In systems with no distributors, the CPU saturates the coil pack, and fires the secondary ignition voltage at just the right time for combustion, and the base reference for ignition timing comes from the cam/crank sensor.
- E. Should the cam/crank sensor or the CPU fail, a system without a distributor needs protection from engine mechanical damage, and this is accomplished with a knock sensor. (Figure 4)

FIGURE 4



- F. The knock sensor counts how many times engine detonation happens in a given period, and if detonation is severe enough, the CPU will retard ignition timing.

(NOTE: There are two systems for knock sensors; one uses a magnet, coil, and magnetostrictive rods which change the voltage in the coil when knocking vibrations are sensed. The other uses piezoelectric crystals which are part of a special silicon semiconductor which also changes electrical voltage when vibrations are sensed.)

- G. Early systems had all or nothing detonation protection that would retard timing a set amount when severe detonation was experienced, but newer systems vary the amount of spark retard in relation to the detonation counts made by the CPU.
- H. Generally, the CPU will retard ignition up to a maximum of 20 degrees from standard settings.

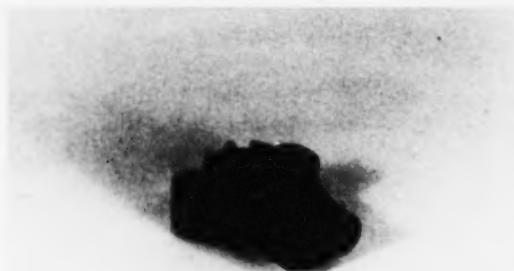
## INFORMATION SHEET

- I. On engines without distributors, anti-knock sensors are standard equipment, and the anti-knock sensors are also on some engines with distributors.

### VIII. The TPS (Throttle Position Sensor)

- A. The TPS is a potentiometer and its input is used with almost every other sensor input to accomplish a variety of tasks.
- B. The CPU uses TPS input to determine fuel and ignition timing requirements for current driving conditions. (Figure 5)

FIGURE 5



- C. The TPS is used to disengage the torque converter clutch for newer (after 1982) vehicles with automatic transmissions, and the CPU will use TPS information to prevent stalling at closed throttle, and to improve performance at wide open throttle.
- D. The CPU uses the TPS as a "fail safe" device because if the MAP sensor failed, the CPU would look at engine RPM and TPS input to supply the required fuel for the current engine load.
- E. The TPS can influence fuel mixture to a slight degree by making the CPU think that the throttle is either nearer to closed or more open than it actually is.

**EXAMPLE:** If TPS voltage is adjusted from .50V to .80V at idle, then the CPU will supply a richen command to the fuel control device, but the change will be slight because the O<sub>2</sub> sensor is still working to keep the air:fuel ratio at 14.7:1.



## INFORMATION SHEET

- F. On some vehicles, the CPU uses the TPS for commanding systems like EGS vacuum, fuel evaporation cannister purging, or other functions using ported vacuum, and this provides more precise control of engine performance.

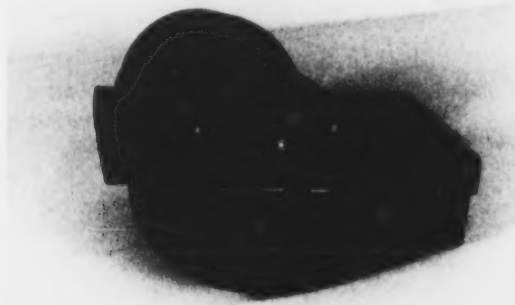
### IX. MAT (Manifold Air Temperature) sensors

- A. When a MAT sensor is used on a fuel-injected engine, its input is used by the CPU to enrich the fuel mixture when the engine is cold.
- B. Less common fuel injection systems use a mass/density fuel control calibration which uses MAT sensor, MAP sensor, and TPS inputs to calculate the volume of air entering the engine, and the CPU then determines the amount of fuel required.

### X. MAF (Mass Air Flow) sensors

- A. With port fuel injection systems, the amount of air coming into the engine must be monitored for best performance, and this is usually accomplished by a MAF sensor.
- B. The MAF sensor is capable of compensating for differences in altitude and humidity.
- C. Depending on type, the MAF sensor has a heat grid or wire which is kept at 75°C above the temperature of incoming air. (Figure 6)

FIGURE 6



- D. The mass of air entering the engine is determined by measuring the electrical load required to keep the MAF sensor at its present temperature.
- E. As air crosses the grid (or wire), it cools the grid, causing the MAF relay to supply more electricity to the grid to maintain the 75°C temperature.

## INFORMATION SHEET

- F. The greater the electrical load at the MAF sensor, the more air there is entering the intake manifold.
- G. The MAF system does not measure the cubic feet of air because that would change with altitude and humidity, instead, the MAF measures actual air density or mass of air.
- H. The electrical power requirement for the MAF is converted into a digital signal to the CPU, and is in the range of 30 Hz to 150 Hz, with the higher frequency indicating a larger mass of air.
- I. The diagnostic readout for the MAF sensor parameter is in grams of air per second.

### XI. Input sensor interaction

- A. All sensors are vital to the operation of a CPU controlled engine, and if one or more sensors is malfunctioning, the engine will develop driveability complaints, and turn on the CPU warning light.
- B. When a coolant sensor fails (open or closed), a cold engine will hesitate because of a lean fuel mixture, and the hesitation would be even more pronounced on a fuel injected engine.
- C. When a TPS fails, the MAP sensor and engine RPM reference would fill in for most engine needs, but on deceleration, the CPU would deliver too much fuel.
- D. In most cases, a hard failure will put the CPU into a "limp home" mode, and the CPU uses a look-up table in the PROM to read inputs that are working, and gets a substitute value for the inoperative sensor(s).

### XII. System output controls

- A. Hot or cold, when an engine is first started, it is in an open loop control mode, and the CPU uses the parameters in the PROM "look-up" table or chart to calculate appropriate outputs for the engine.
- B. For the engine to go into a closed loop mode, several things have to happen:
  - 1. The O<sub>2</sub> sensor must be warmed up to approximately 600°F.
  - 2. The CPU timer, which allows the engine to stabilize before entering closed loop operation, must expire in order to avoid irregularities in engine performance.
  - 3. All other sensors must be sending valid data to the CPU, and although the CPU can obtain closed loop status if some sensors malfunction, the CPU will generally not allow closed loop operation if the CPU warning light is on.

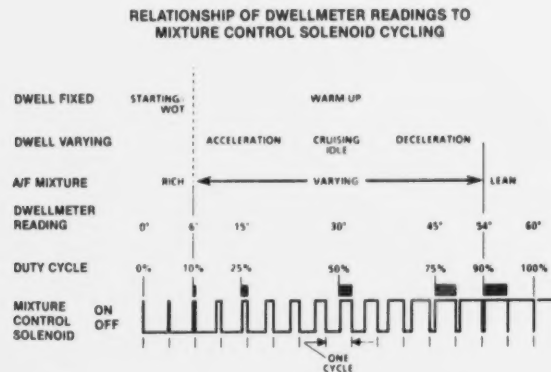
## INFORMATION SHEET

- C. While in the closed loop mode, the CPU receives continuing input data from all sensors so it can evaluate conditions and determine the correct amount of fuel and timing necessary to obtain optimum emissions control and engine performance.
- D. During closed loop operation, the CPU controls most emissions systems like the evaporative charcoal cannister purging, air pump diversion to needed areas, and EGR vacuum.

### XIII. Pulse width and on time functions

- A. The CPU controls fuel distribution at a rate of 10 cycles per second, and one complete on and off cycle, which is 1/10th of a second, is called a "pulse."
- B. Pulse width is another significant term because it refers to the amount of time that the CPU energizes the electric solenoid in the fuel injector, or the carburetor fuel control solenoid.
- C. The amount of time that the CPU commands fuel delivery is called "on time" or duty cycle, and determines how much fuel will flow into the intake system. (Figure 7)

FIGURE 7



Courtesy Chevrolet Division, General Motors Corporation

## INFORMATION SHEET

### XIV. Fuel control systems

- A. On a carbureted fuel system, the CPU controls the pulse width of the fuel control solenoid, and when the solenoid is energized, metering rods in the primary metering jets are drawn downward to allow more fuel to pass by the jet and enrich the air:fuel ratio.
- B. Fuel injected systems are either throttle mounted or manifold mounted, and both systems use an electric fuel pump to supply pressurized fuel at the injector whenever the engine is running.
- C. The electrical relay that supplies power to the fuel pump has a built-in timer which prevents the pump from running more than a few seconds if the CPU does not receive an engine RPM signal.
- D. When the CPU energizes the solenoid inside the injector itself, the injector plunger is drawn up off its seat, and this allows the pressurized fuel to discharge.
- E. When the CPU de-energizes the solenoid inside the injector itself, the injector plunger reseats and stops fuel flow.
- F. The fuel discharged from the tip of an injector gives a fine atomized spray that is far better than any carburetor can provide.
- G. Throttle mounted injectors spray atomized fuel on top of the throttle plate where the throttle plate opening regulates the fuel mist/air mixture into the intake manifold plenum, and on into the combustion chamber.
- H. Manifold port injectors (manifold mounted) are located in the intake manifold itself, and they spray atomized fuel directly on top of the intake valve in the cylinder head, and the injector is turned on/off by CPU command.
- I. The throttle body of a manifold port injected system delivers only air while the throttle mounted and carbureted systems deliver an air:fuel mixture.
- J. Some manifold port injected systems use a cold start injector, and this injector is controlled by timers and relays to insure that it supplies fuel only for cold driveability requirements.

### XV. Ignition spark timing control

- A. Most CPU controlled systems employ varying degrees of CPU control over timing through sensor input.
- B. The most basic CPU controlled ignition timing systems uses a conventional vacuum advance diaphragm, and the CPU controls the timing that was once controlled by the centrifugal advance function.

## INFORMATION SHEET

- C. Other systems with no vacuum advance diaphragm are fully CPU controlled.
- D. The distributor provides the CPU with the engine RPM reference, the data is compared with other sensor inputs, and the CPU commands the required ignition timing.
- E. With a CPU controlling timing, emissions control is better.

**EXAMPLE:** On deceleration, traditional systems are infamous for high HC output, but a CPU controlled engine will run as much as 32 degrees extra advance to burn off excess HCs.

- F. Systems without a distributor must have a sensor to tell the CPU when to fire the ignition coil for secondary spark to the plugs.
- G. Most systems use both crankshaft and camshaft sensors to replace the distributor reference, and both the crankshaft and camshaft sensors deliver an impulse to the CPU once for each revolution.
- H. The crank sensor is usually mounted on the block behind the crank pulley, and a metal vane on the back of the crank pulley rotates between the two halves of the crank sensor (it is a hall effect switch) so that a gap in the vane at TDC (top dead center) will trigger the switch.
- I. Some camshaft sensors are located in the engine timing cover, and are triggered by a magnet located in the front of the camshaft timing gear, and as the magnet passes the cam sensor, a reference impulse is sent to the CPU.
- J. The camshaft sensor lets the CPU know when the crankshaft is at TDC for firing cylinder #1, or at TDC for exhausting cylinder #1.
- K. Systems without distributors use anti-knock sensors, and some engines with distributors use anti-knock sensors too.
- L. An anti-knock sensor is a crystal design that registers any pre-ignition detonation so the CPU can count how many inputs per second occur, and then compare the count with timing output to determine whether or not timing should be retarded.
- M. Early systems retarded timing 20 degrees or nothing at all, but modern systems retard timing in 2 degree intervals to allow a smooth, safe engine control that prevents damage to pistons.

### **XVI. EGR (Exhaust Gas Recirculation) controls**

- A. All EGR valves route burned exhaust gases from the exhaust stream into the intake manifold to mix with the air:fuel mixture, and that is how EGRs reduce harmful NO<sub>x</sub> (nitrous oxides).

## INFORMATION SHEET

- B. Another important EGR function is that it lowers combustion temperature and helps eliminate ignition detonation. (Figure 8)

FIGURE 8



- C. EGR valves are vacuum controlled, and one type is connected to a ported vacuum while the other type is controlled by a CPU and a vacuum control valve that is pulse width modulated.
- D. Some EGR systems have a thermal switch in the cooling system to block vacuum to the EGR valve when the engine is cold.
- E. Some systems use a vacuum delay valve which allows the engine to reach a higher RPM before the EGR valve goes into operation, and the transition to EGR operation is smoother.
- F. Because the CPU controls the pulse width of the vacuum valve, CPU controlled systems have finer control of EGR valve input, and provide extremely smooth transition because the vacuum from the vacuum valve to the EGR valve is precisely controlled.
- G. Even finer transition control is provided by the vent in the vacuum valve, because the CPU can command a quick drop (through venting) in vacuum output to the EGR valve.

### XVII. Emission control devices

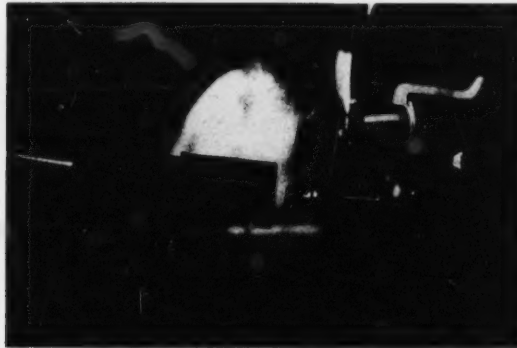
- A. The CPU controlled engine was developed in response to federal legislation designed to reduce harmful pollutants in exhaust emissions.
- B. Keeping the air:fuel ratio at an optimum of 14.7:1 helps control emissions, but the CPU controls other devices that also help clean the exhaust stream.
- C. The CPU controls the air supply to both functions in a dual bed catalytic converter.



## INFORMATION SHEET

- D. Air flow controlled by the CPU is supplied by an air pump through electrically controlled diverter valves which direct air to either on of the two beds or vents air to the atmosphere.
- E. The beds contain different materials, and while one bed may require extra oxygen to work effectively, the other may work best with less oxygen.
- F. The CPU controls the hydraulic circuit that locks the torque converter turbine shaft to the cover, and this saves 3 to 4% slippage that occurs at highway speeds, improves fuel economy, and contributes to cleaner exhaust.
- G. Most late model vehicles (1981 and newer) have some sort of evaporative control system to keep fuel vapors from escaping into the atmosphere. (Figure 9)

FIGURE 9



- H. Most evaporative systems employ a charcoal cannister that stores the vapors until they can be purged back into the intake system and burned.
- I. The CPU may be used to control a purge valve on a charcoal cannister.

## COMPUTERIZED ENGINE CONTROLS UNIT VII

### JOB SHEET #1 — TEST OXYGEN SENSOR OPERATIONS

#### A. Tools and materials

1. Vehicle as selected by instructor
2. Appropriate service manual
3. Fender covers, wheel blocks, and safety exhaust
4. Jumper lead set (16-gauge wire)
5. DVOM
6. Pencil
7. Watch with second hand
8. Safety glasses

#### B. Routine #1 — Measuring oxygen sensor voltage

1. Bring vehicle into shop area, open hood, and install fender covers.
2. Put on safety glasses.
3. Block wheels and install exhaust removal system.
4. Locate the oxygen sensor which should be in the exhaust manifold or in the Y pipe just before the catalytic converter.
5. Determine whether the sensor has one or two wires; early model sensors are a two-wire design, but later models have only one wire.
6. Make sure the ignition is turned off, and then disconnect the oxygen sensor wiring connector by releasing the lock tab on the side of the connector.

**(CAUTION: Do not place any wires on the exhaust system because they will melt and short out the test meter when the exhaust heats up.)**

7. Connect the DVOM probes to the oxygen sensor, and use Figure 1 as a reference. (Figure 1)



## JOB SHEET #1

FIGURE 1



8. Switch the DVOM to DC on the 2 volt scale, and connect the wires according to Figure 1.
9. Record the voltage output reading from the oxygen sensor: \_\_\_\_\_.
10. Start the engine and let it idle.
11. Record the voltage reading from the oxygen sensor after two minutes of idling: \_\_\_\_\_.
12. Run the engine at 2,000 RPM until the voltage reaches 450mv, and is fluctuating rapidly.
13. Allow the engine to idle again, and record the voltage reading from the oxygen sensor again: \_\_\_\_\_.
14. Compare your last two voltage readings from steps 11 and 13.
15. Turn the ignition off.
16. Discuss your findings with your instructor, and summarize your conclusion:

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## C. Routine #2 — Measuring cross counts

1. Put on safety glasses.

## JOB SHEET #1

2. Disconnect the DVOM from the oxygen sensor.
3. Install the jumper leads from the oxygen sensor connector to the harness connector so that the sensor is not connected to the CPU. (Figure 2)

FIGURE 2



4. Connect the DVOM probes to the jumper leads as indicated in Figure 2.
5. Start the engine and let it idle.
6. Record the voltage reading at the oxygen sensor leads: \_\_\_\_\_.
7. Run the engine at 2,000 RPM for 2 minutes, and record the average oxygen sensor reading: \_\_\_\_\_.
8. Let the engine idle, and record the oxygen sensor voltage above 450mv: \_\_\_\_\_, or below 450mv: \_\_\_\_\_.
9. Watch as the digital readout varies, and count how many times the voltage crosses the 450mv mid-point in a five second interval: \_\_\_\_\_.
10. Answer the following questions regarding your finding:
  - a. If the voltage is consistently above 450mv, what air:fuel mixture would that indicate: Rich: \_\_\_\_\_ or Lean: \_\_\_\_\_.
  - b. If the voltage is consistently below 450mv, what air:fuel mixture would that indicate: Rich: \_\_\_\_\_ or Lean: \_\_\_\_\_.

## JOB SHEET #1

11. Discuss your findings with your instructor, and state why you think it is important that the oxygen sensor voltage stay around 450mv: \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_
12. Turn the ignition off.
13. Disconnect the DVOM, jumper leads, and reconnect the oxygen sensor to the harness.
14. Clear any diagnostic codes that you may have set.  
(NOTE: Check service manual.)  
☐ Have your instructor check your work.
15. Remove fender covers and close hood.
16. Start engine, verify proper operation, and turn ignition off.
17. Return tools and materials to proper storage.

## COMPUTERIZED ENGINE CONTROLS UNIT VII

### JOB SHEET #2 — TEST MAP SENSOR OPERATIONS

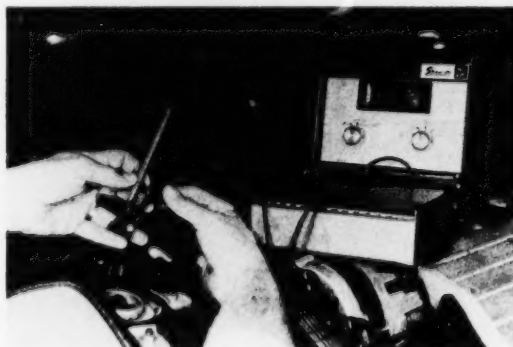
#### A. Tools and materials

1. Vehicle as selected by instructor
2. Appropriate service manual
3. DVOM
4. Hand held vacuum gauge/pump
5. Jumper leads (16-gauge wire)
6. Hand tools as required
7. Fender covers, wheel blocks, and safety exhaust
8. Safety glasses

#### B. Procedure

1. Bring vehicle into shop area, open hood, and install fender covers.
2. Put on safety glasses, block wheels, and install exhaust removal system.
3. Locate the MAP sensor.
4. Disconnect the wiring harness connector from the sensor.
5. Connect the jumper leads in series with the sensor wiring, and then connect the DVOM as shown in Figure 1.

FIGURE 1



## JOB SHEET #2

6. Turn the ignition key on, but don't start the engine.
7. Record the voltage at the sensor output: \_\_\_\_\_.
8. Start the engine, and record the voltage output of the sensor at idle: \_\_\_\_\_.
9. Quickly accelerate the engine, and record the highest voltage seen on the DVOM: \_\_\_\_\_.
10. Turn the ignition off, and disconnect the vacuum hose from the MAP sensor.
11. Connect a hand held vacuum pump to the MAP sensor.
12. Turn the key on, **BUT DO NOT START THE ENGINE**, and record the voltage from the MAP sensor with a zero reading on the vacuum gauge: \_\_\_\_\_.
13. Pump up 10 inches of vacuum on the gauge, and record the sensor voltage: \_\_\_\_\_.
14. Pump up 20 inches of vacuum on the gauge, and record the sensor voltage: \_\_\_\_\_.
15. Compare your latest readings with the readings you took while the engine was running, and discuss your findings with your instructor.
16. Reconnect vacuum lines and wiring, remove fender covers, and close hood.  
☐ Have your instructor check your work.
17. Start engine, verify operation, and turn ignition off.
18. Return tools and materials to proper storage.

## COMPUTERIZED ENGINE CONTROLS UNIT VII

### JOB SHEET #3 — TEST ENGINE COOLANT TEMPERATURE SENSOR OPERATIONS

#### A. Tools and materials

1. Vehicle as selected by instructor
2. Appropriate service manual
3. DVOM
4. Digital pyrometer (optional)
5. Two jumper leads, one with clips (16-gauge wire)
6. Coolant specific gravity tester
7. Hand tools as required
8. Fender covers, wheel blocks, and safety exhaust
9. Safety glasses

#### B. Routine #1 — Checking coolant quality

1. Bring vehicle into shop area, open hood, install fender covers, and permit radiator to cool.
2. Put on safety glasses, block wheels, and install safety exhaust system.
3. Remove the radiator cap.

(NOTE: If the system is still warm or hot, removing the cap on the recovery tank will provide suitable access to the coolant.)

4. Take a sample of the coolant in the coolant tester.

(NOTE: This is an important first step, because you cannot accurately test a coolant sensor if the coolant is contaminated.)

5. Record the reading on the coolant tester: \_\_\_\_\_ .

#### C. Routine #2 — Testing coolant temperature sensor operations

1. Put on safety glasses.

## JOB SHEET #3

2. Locate coolant sensor, and since they are sometimes in difficult to find locations, you may speed the process by consulting your service manual.
3. Disconnect the wiring harness from the sensor.
4. Set your DVOM to read ohms, and check the resistance across the sensor.  
(NOTE: See the temperature/resistance chart in the service manual.)
5. Connect the jumper leads in series with the sensor wiring, and connect the DVOM as shown in Figure 1.

FIGURE 1



6. Turn the ignition key on, but **DON'T START THE ENGINE.**
7. Record the voltage at the coolant sensor: \_\_\_\_\_ .  
(NOTE: Remember that the sensor is a thermistor.)
8. Start the engine, and let it idle for 2 minutes, and then record the voltage at the sensor: \_\_\_\_\_ .
9. Allow the engine to warm up to normal operating temperature, and then record the voltage at the sensor: \_\_\_\_\_ .  
☐ Compare your findings, and discuss your findings with your instructor.
10. Turn engine off, and reconnect coolant sensor wires.
11. Start engine, verify proper operation, and turn ignition off.
12. Return tools and materials to proper storage.

## COMPUTERIZED ENGINE CONTROLS UNIT VII

### JOB SHEET #4 — TEST TPS OPERATIONS

#### A. Tools and materials

1. Vehicle as selected by instructor
2. Appropriate service manual
3. DVOM
4. Hand tools as required
5. Three jumper leads (16-gauge wire)
6. Fender covers, wheel blocks, and safety exhaust
7. Pencil
8. Safety glasses

#### B. Procedure

1. Bring vehicle into shop area, open hood, and install fender covers.
2. Put on safety glasses, block wheels, and install exhaust removal system.
3. Locate sensor.  
  
(NOTE: You may have to remove the air cleaner assembly.)
4. Disconnect the wiring harness from the TPS.
5. Connect the jumper leads into series with the sensor wiring, check DVOM scale, and connect the DVOM as shown in Figure 1.

FIGURE 1





**JOB SHEET #4**

6. Turn the ignition on, but **DON'T START THE ENGINE.**
7. Record the voltage from the TPS with the throttle closed: \_\_\_\_\_.
8. Open the throttle to the wide open position, and record the TPS voltage: \_\_\_\_\_.
9. Release the throttle to approximately  $\frac{1}{2}$  throttle opening, and record the TPS voltage: \_\_\_\_\_.
10. Move the throttle gradually through its complete range, and note the varying voltages: \_\_\_\_\_  
  
(NOTE: Some manufacturers call this the "TPS sweep.")
11. Discuss your findings with your instructor, and summarize your findings about TPS operations in relation to throttle opening:  
\_\_\_\_\_  
\_\_\_\_\_
12. Turn the ignition off, and reinstall air cleaner assembly.
13. Remove the fender covers, and close the hood.  
☐ Have your instructor check your work.
14. Start engine, verify proper operation, and turn ignition off.
15. Return tools and materials to proper storage.

## COMPUTERIZED ENGINE CONTROLS UNIT VII

### JOB SHEET #5 — TEST EGR VALVE OPERATIONS

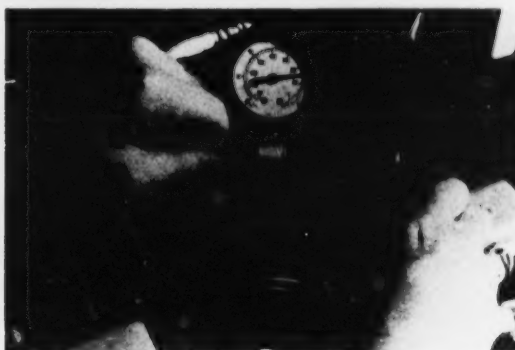
#### A. Tools and materials

1. Vehicle as selected by instructor
2. Appropriate service manual
3. Hand tools as required
4. Hand held vacuum pump/gauge and a  $\frac{5}{32}$ " vacuum tee
5. Fender covers, wheel blocks, and safety exhaust
6. Safety glasses

#### B. Procedure

1. Bring vehicle into shop area, open hood, and install fender covers.
2. Put on safety glasses, block wheels, and install exhaust removal system.
3. Locate the EGR valve, it is usually in the intake manifold toward the rear of the engine.
4. Use the vacuum tee to insert the vacuum gauge into the line at the EGR valve. (Figure 1)

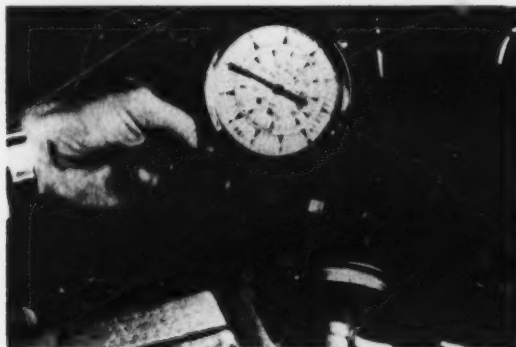
FIGURE 1



## JOB SHEET #5

5. Start the engine, let it idle, and record vacuum to EGR: \_\_\_\_\_.
6. Open throttle briefly, note any movement on the vacuum gauge, and record the highest vacuum reading: \_\_\_\_\_.
7. Remove the vacuum tee and connect the vacuum pump to the EGR valve. (Figure 2)

FIGURE 2



8. Use vacuum pump to open the EGR valve.
9. Record what happened to the engine: \_\_\_\_\_, and then briefly state why it happened: \_\_\_\_\_  
\_\_\_\_\_
10. Allow the engine to reach normal operating temperature, and then repeat steps 5 and 6, and record your findings: \_\_\_\_\_  
\_\_\_\_\_
11. Discuss your findings with your instructor, and summarize why you think EGR operation is blocked for a cold engine: \_\_\_\_\_  
\_\_\_\_\_
12. Return EGR vacuum lines, and anything else removed to access the EGR valve.
13. Verify proper engine operation, and turn ignition off.
14. Remove the fender cover, and close the hood.  
☐ Have your instructor check your work.
15. Return tools and materials to proper storage.

## COMPUTERIZED ENGINE CONTROLS UNIT VII

### JOB SHEET #6 — ADJUST IGNITION TIMING

#### A. Tools and materials

1. Vehicle as selected by instructor
2. Appropriate service manual
3. Fender covers, wheel blocks, and safety exhaust
4. Basic hand tools
5. Timing light/meter
6. Safety glasses

#### B. Procedure

1. Bring vehicle into shop area, open hood, and install fender covers.
2. Put on safety glasses.
3. Block drive wheels, and install exhaust removal.
4. Open your service manual to the section covering ignition timing.
5. Start the engine and let it warm to normal operating temperature.
6. Follow service manual instructions for blocking the EGR, and disconnecting the bypass wire.

(NOTE: This step may vary, depending on the make and model.)

7. Use the timing light/meter to measure base timing.

(NOTE: If the meter requires a preset timing offset, use the correct number.)

8. Check the timing, and compare it with timing specifications in the service manual.
9. Reconnect any devices disabled in order to set timing.
10. Run the engine through varying RPM ranges to assure proper operation.

☐ Have your instructor check your work.

**JOB SHEET #6**

11. Remove timing light/meter, fender covers, and close hood.
12. Return tools and materials to proper storage.

## COMPUTERIZED ENGINE CONTROLS UNIT VII

### PRACTICAL TEST #1 JOB SHEET #1 — TEST OXYGEN SENSOR OPERATIONS

Student's name \_\_\_\_\_

Date \_\_\_\_\_

Evaluator's name \_\_\_\_\_

Attempt no. \_\_\_\_\_

Student instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

#### PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

| The student:                                       | YES                         | NO                       |
|----------------------------------------------------|-----------------------------|--------------------------|
| 1. Wore safety glasses.                            | 1. <input type="checkbox"/> | <input type="checkbox"/> |
| 2. Prepared vehicle safely.                        | 2. <input type="checkbox"/> | <input type="checkbox"/> |
| 3. Disconnected oxygen sensor properly.            | 3. <input type="checkbox"/> | <input type="checkbox"/> |
| 4. Used DVOM properly.                             | 4. <input type="checkbox"/> | <input type="checkbox"/> |
| 5. Made and recorded appropriate voltage readings. | 5. <input type="checkbox"/> | <input type="checkbox"/> |
| 6. Measured cross counts properly.                 | 6. <input type="checkbox"/> | <input type="checkbox"/> |
| 7. Cleared diagnostic codes properly.              | 7. <input type="checkbox"/> | <input type="checkbox"/> |
| 8. Secured vehicle, tools and materials.           | 7. <input type="checkbox"/> | <input type="checkbox"/> |

Evaluator's comments: \_\_\_\_\_

 \_\_\_\_\_  
 \_\_\_\_\_

## JOB SHEET #1 PRACTICAL TEST

### PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another test procedure must be submitted for evaluation.)

Criteria:

|                        |                         |                          |                      |                          |
|------------------------|-------------------------|--------------------------|----------------------|--------------------------|
| Tool and Equipment Use | Excellent<br>4          | Good<br>3                | Fair<br>2            | Poor<br>1                |
| Mastery of Procedure   | Confident<br>4          | Acceptable<br>3          | Hesitant<br>2        | Unacceptable<br>1        |
| Vehicle Care           | Neat and Clean<br>4     | Clean<br>3               | Careless<br>2        | Sloppy<br>1              |
| Safety                 | Carefully observed<br>4 | Acceptably observed<br>3 | Poorly observed<br>2 | Improperly observed<br>1 |

EVALUATOR'S COMMENTS: \_\_\_\_\_

#### PERFORMANCE EVALUATION KEY

- 4 — Skilled — Can perform job with no additional training.
- 3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
- 2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
- 1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

## COMPUTERIZED ENGINE CONTROLS UNIT VII

### PRACTICAL TEST #2 JOB SHEET #2 — TEST MAP SENSOR OPERATIONS

Student's name \_\_\_\_\_

Date \_\_\_\_\_

Evaluator's name \_\_\_\_\_

Attempt no. \_\_\_\_\_

Student instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

#### PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

| The student:                                       | YES                         | NO                       |
|----------------------------------------------------|-----------------------------|--------------------------|
| 1. Wore safety glasses.                            | 1. <input type="checkbox"/> | <input type="checkbox"/> |
| 2. Prepared vehicle safely.                        | 2. <input type="checkbox"/> | <input type="checkbox"/> |
| 3. Disconnected MAP sensor properly.               | 3. <input type="checkbox"/> | <input type="checkbox"/> |
| 4. Used DVOM properly.                             | 4. <input type="checkbox"/> | <input type="checkbox"/> |
| 5. Made and recorded appropriate voltage readings. | 5. <input type="checkbox"/> | <input type="checkbox"/> |
| 6. Made vacuum tests on MAP sensor properly.       | 6. <input type="checkbox"/> | <input type="checkbox"/> |
| 7. Compared test readings.                         | 7. <input type="checkbox"/> | <input type="checkbox"/> |
| 8. Secured vehicle, tools and materials.           | 8. <input type="checkbox"/> | <input type="checkbox"/> |

Evaluator's comments: \_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_



## JOB SHEET #2 PRACTICAL TEST

### PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another test procedure must be submitted for evaluation.)

Criteria:

|                        |                         |                          |                      |                          |
|------------------------|-------------------------|--------------------------|----------------------|--------------------------|
| Tool and Equipment Use | Excellent<br>4          | Good<br>3                | Fair<br>2            | Poor<br>1                |
| Mastery of Procedure   | Confident<br>4          | Acceptable<br>3          | Hesitant<br>2        | Unacceptable<br>1        |
| Vehicle Care           | Neat and Clean<br>4     | Clean<br>3               | Careless<br>2        | Sloppy<br>1              |
| Safety                 | Carefully Observed<br>4 | Acceptably Observed<br>3 | Poorly Observed<br>2 | Improperly Observed<br>1 |

EVALUATOR'S COMMENTS: \_\_\_\_\_

#### PERFORMANCE EVALUATION KEY

- 4 — Skilled — Can perform job with no additional training.
- 3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
- 2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
- 1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

## COMPUTERIZED ENGINE CONTROLS UNIT VII

### PRACTICAL TEST #3 JOB SHEET #3 — TEST ENGINE COOLANT TEMPERATURE SENSOR OPERATIONS

Student's name \_\_\_\_\_

Date \_\_\_\_\_

Evaluator's name \_\_\_\_\_

Attempt no. \_\_\_\_\_

Student instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

#### PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:

|                                               | YES                         | NO                       |
|-----------------------------------------------|-----------------------------|--------------------------|
| 1. Wore safety glasses.                       | 1. <input type="checkbox"/> | <input type="checkbox"/> |
| 2. Prepared vehicle safely.                   | 2. <input type="checkbox"/> | <input type="checkbox"/> |
| 3. Tested coolant sample.                     | 3. <input type="checkbox"/> | <input type="checkbox"/> |
| 4. Connected DVOM to coolant sensor properly. | 4. <input type="checkbox"/> | <input type="checkbox"/> |
| 5. Made voltage recordings in proper order.   | 5. <input type="checkbox"/> | <input type="checkbox"/> |
| 6. Compared voltage readings.                 | 6. <input type="checkbox"/> | <input type="checkbox"/> |
| 7. Secured vehicle, tools and materials.      | 7. <input type="checkbox"/> | <input type="checkbox"/> |

Evaluator's comments: \_\_\_\_\_

 \_\_\_\_\_  
 \_\_\_\_\_

## JOB SHEET #3 PRACTICAL TEST

### PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another test procedure must be submitted for evaluation.)

Criteria:

|                        |                         |                          |                      |                          |
|------------------------|-------------------------|--------------------------|----------------------|--------------------------|
| Tool and Equipment Use | Excellent<br>4          | Good<br>3                | Fair<br>2            | Poor<br>1                |
| Mastery of Procedure   | Confident<br>4          | Acceptable<br>3          | Hesitant<br>2        | Unacceptable<br>1        |
| Vehicle Care           | Neat and Clean<br>4     | Clean<br>3               | Careless<br>2        | Sloppy<br>1              |
| Safety                 | Carefully Observed<br>4 | Acceptably Observed<br>3 | Poorly Observed<br>2 | Improperly Observed<br>1 |

EVALUATOR'S COMMENTS: \_\_\_\_\_

#### PERFORMANCE EVALUATION KEY

- 4 — Skilled — Can perform job with no additional training.
- 3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
- 2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
- 1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

# **COMPUTERIZED ENGINE CONTROLS UNIT VII**

## **PRACTICAL TEST #4 JOB SHEET #4 — TEST TPS OPERATIONS**

Student's name \_\_\_\_\_

Date \_\_\_\_\_

Evaluator's name \_\_\_\_\_

Attempt no. \_\_\_\_\_

Student instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

### PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

| The student:                                                     | YES                         | NO                       |
|------------------------------------------------------------------|-----------------------------|--------------------------|
| 1. Wore safety glasses.                                          | 1. <input type="checkbox"/> | <input type="checkbox"/> |
| 2. Prepared vehicle safely.                                      | 2. <input type="checkbox"/> | <input type="checkbox"/> |
| 3. Located TPS, and connected DVOM properly.                     | 3. <input type="checkbox"/> | <input type="checkbox"/> |
| 4. Made and recorded voltage readings at proper throttle ranges. | 4. <input type="checkbox"/> | <input type="checkbox"/> |
| 5. Made and recorded voltage through complete range.             | 5. <input type="checkbox"/> | <input type="checkbox"/> |
| 6. Summarized findings.                                          | 6. <input type="checkbox"/> | <input type="checkbox"/> |
| 7. Secured vehicle, tools and materials.                         | 7. <input type="checkbox"/> | <input type="checkbox"/> |

Evaluator's comments: \_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

## JOB SHEET #4 PRACTICAL TEST

### PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another test procedure must be submitted for evaluation.)

Criteria: \_\_\_\_\_

Tool and  
Equipment Use

Excellent  
4

Good  
3

Fair  
2

Poor  
1

Mastery of  
Procedure

Confident  
4

Acceptable  
3

Hesitant  
2

Unacceptable  
1

Vehicle  
Care

Neat and  
Clean  
4

Clean  
3

Careless  
2

Sloppy  
1

Safety

Carefully  
Observed  
4

Acceptably  
Observed  
3

Poorly  
Observed  
2

Improperly  
Observed  
1

EVALUATOR'S COMMENTS: \_\_\_\_\_

#### PERFORMANCE EVALUATION KEY

- 4 — Skilled — Can perform job with no additional training.
- 3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
- 2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
- 1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

## COMPUTERIZED ENGINE CONTROLS UNIT VII

### PRACTICAL TEST #5 JOB SHEET #5 — TEST EGR VALVE OPERATIONS

Student's name \_\_\_\_\_

Date \_\_\_\_\_

Evaluator's name \_\_\_\_\_

Attempt no. \_\_\_\_\_

Student instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

#### PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

| The student:                                                        | YES                         | NO                       |
|---------------------------------------------------------------------|-----------------------------|--------------------------|
| 1. Wore safety glasses.                                             | 1. <input type="checkbox"/> | <input type="checkbox"/> |
| 2. Prepared vehicle safely.                                         | 2. <input type="checkbox"/> | <input type="checkbox"/> |
| 3. Used vacuum tee and vacuum gauge properly.                       | 3. <input type="checkbox"/> | <input type="checkbox"/> |
| 4. Used pump vacuum to open EGR valve.                              | 4. <input type="checkbox"/> | <input type="checkbox"/> |
| 5. Recorded vacuum readings at appropriate engine operating speeds. | 5. <input type="checkbox"/> | <input type="checkbox"/> |
| 6. Summarized findings.                                             | 6. <input type="checkbox"/> | <input type="checkbox"/> |
| 7. Secured vehicle, tools and materials.                            | 7. <input type="checkbox"/> | <input type="checkbox"/> |

Evaluator's comments: \_\_\_\_\_

 \_\_\_\_\_  
 \_\_\_\_\_

## JOB SHEET #5 PRACTICAL TEST

### PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another test procedure must be submitted for evaluation.)

Criteria:

|                        |                         |                          |                      |                          |
|------------------------|-------------------------|--------------------------|----------------------|--------------------------|
| Tool and Equipment Use | Excellent<br>4          | Good<br>3                | Fair<br>2            | Poor<br>1                |
| Mastery of Procedure   | Confident<br>4          | Acceptable<br>3          | Hesitant<br>2        | Unacceptable<br>1        |
| Vehicle Care           | Neat and Clean<br>4     | Clean<br>3               | Careless<br>2        | Sloppy<br>1              |
| Safety                 | Carefully Observed<br>4 | Acceptably Observed<br>3 | Poorly Observed<br>2 | Improperly Observed<br>1 |

EVALUATOR'S COMMENTS: \_\_\_\_\_

#### PERFORMANCE EVALUATION KEY

- 4 — Skilled — Can perform job with no additional training.
- 3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
- 2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
- 1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)



## COMPUTERIZED ENGINE CONTROLS UNIT VII

### PRACTICAL TEST #6 JOB SHEET #6 — ADJUST IGNITION TIMING

Student's name \_\_\_\_\_

Date \_\_\_\_\_

Evaluator's name \_\_\_\_\_

Attempt no. \_\_\_\_\_

Student instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

#### PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:

|                                                 | YES                         | NO                       |
|-------------------------------------------------|-----------------------------|--------------------------|
| 1. Wore safety glasses.                         | 1. <input type="checkbox"/> | <input type="checkbox"/> |
| 2. Prepared vehicle safely.                     | 2. <input type="checkbox"/> | <input type="checkbox"/> |
| 3. Referenced service manual properly.          | 3. <input type="checkbox"/> | <input type="checkbox"/> |
| 4. Prepared properly for timing test.           | 4. <input type="checkbox"/> | <input type="checkbox"/> |
| 5. Tested base timing.                          | 5. <input type="checkbox"/> | <input type="checkbox"/> |
| 6. Made timing comparisons with specifications. | 6. <input type="checkbox"/> | <input type="checkbox"/> |
| 7. Replaced parts disconnected for testing.     | 7. <input type="checkbox"/> | <input type="checkbox"/> |
| 8. Secured vehicle, tools and materials.        | 8. <input type="checkbox"/> | <input type="checkbox"/> |

Evaluator's comments: \_\_\_\_\_

 \_\_\_\_\_  
 \_\_\_\_\_



## JOB SHEET #6 PRACTICAL TEST

### PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another test procedure must be submitted for evaluation.)

Criteria:

|                        |                         |                          |                      |                          |
|------------------------|-------------------------|--------------------------|----------------------|--------------------------|
| Tool and Equipment Use | Excellent<br>4          | Good<br>3                | Fair<br>2            | Poor<br>1                |
| Mastery of Procedure   | Confident<br>4          | Acceptable<br>3          | Hesitant<br>2        | Unacceptable<br>1        |
| Vehicle Care           | Neat and Clean<br>4     | Clean<br>3               | Careless<br>2        | Sloppy<br>1              |
| Safety                 | Carefully Observed<br>4 | Acceptably Observed<br>3 | Poorly Observed<br>2 | Improperly Observed<br>1 |

EVALUATOR'S COMMENTS: \_\_\_\_\_

#### PERFORMANCE EVALUATION KEY

- 4 — Skilled — Can perform job with no additional training.
- 3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
- 2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
- 1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

# COMPUTERIZED ENGINE CONTROLS UNIT VII

## TEST

NAME \_\_\_\_\_

SCORE \_\_\_\_\_

1. Match terms related to computerized engine controls with their correct definitions.

- |                                                                                                                                                                                                                    |                                  |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------|
| <p>_____a. A computer that receives inputs from various sensors, and compares them with pre-determined values in order to command required engine controls</p>                                                     | <p>1. Open loop operations</p>   |
| <p>_____b. Devices that tell the CPU about engine operating conditions at a given moment</p>                                                                                                                       | <p>2. Parameter</p>              |
| <p>_____c. Devices that tell the CPU about non-engine operating conditions such as vehicle speed and passenger compartment temperature</p>                                                                         | <p>3. Base timing</p>            |
| <p>_____d. A silicon chip that has stored on it the parameters for such specific applications as timing and fuel delivery for a cold engine with half throttle opening</p>                                         | <p>4. Inverse relationship</p>   |
| <p>_____e. The first operating mode after start-up when engine operations are being controlled by specific parameters in PROM</p>                                                                                  | <p>5. NO<sub>x</sub></p>         |
| <p>_____f. An operating mode where all sensors are operational, and engine operations are controlled by constant CPU updates to engine parameters such as air:fuel ratio, timing, and emission control devices</p> | <p>6. Pulse width</p>            |
| <p>_____g. A scale defining the maximum and minimum limit that a value must have to meet a standard</p>                                                                                                            | <p>7. CPU</p>                    |
| <p>_____h. A light on the drive information panel that warns of a system problem with one or more sensor inputs</p>                                                                                                | <p>8. PROM</p>                   |
| <p>_____i. A condition in which the increase of one parameter will cause an increase in a related parameter</p>                                                                                                    | <p>9. Closed loop operations</p> |
|                                                                                                                                                                                                                    | <p>10. Direct relationship</p>   |
|                                                                                                                                                                                                                    | <p>11. Engine sensors</p>        |
|                                                                                                                                                                                                                    | <p>12. CPU warning light</p>     |
|                                                                                                                                                                                                                    | <p>13. Vehicle sensors</p>       |

## TEST

- \_\_\_\_j. A condition in which the increase of one parameter will cause a decrease in a related parameter
  - \_\_\_\_k. Timing mechanically set without CPU interference
  - \_\_\_\_l. The unit of measurement used by the CPU to control fuel output; it is based on 10 cycles per second, and the ON time of each cycle is controlled by the CPU
  - \_\_\_\_m. Oxides of nitrogen that are part of exhaust emissions that must be minimal to meet EPA standards
2. Select true statements concerning O<sub>2</sub> sensors by placing an "X" beside each statement that is true.

(NOTE: For a statement to be true, all parts of the statement must be true.)

- \_\_\_\_a. The oxygen sensor is located in the carburetor system near the engine, and measures the amount of oxygen content in the carburetor.
- \_\_\_\_b. The oxygen sensor is a lamda sensor with a zirconium electrolyte between two platinum plates with one plate exposed to the carburetor system, and the other plate exposed to the atmosphere.
- \_\_\_\_c. When the air:fuel ratio is lean, the exhaust stream contains more oxygen, and when the air:fuel ratio is rich, the exhaust stream contains less oxygen.
- \_\_\_\_d. The oxygen sensor creates a voltage of between .2 and 1.0 volts by electron transfer in the zirconium electrolyte between the platinum plates.
- \_\_\_\_e. If the air:fuel ratio is lean, the oxygen sensor will generate a higher voltage, and if the air:fuel ratio is rich, the oxygen sensor will generate a lower voltage.
- \_\_\_\_f. Oxygen sensor/CPU interaction is continuous:
  - 1) The CPU sends a .45 volt signal to the oxygen sensor at all times.
  - 2) When the sensor is generating a low voltage, the sensor drains some of the CPU signal, and brings the CPU signal down.
  - 3) When the sensor is generating a high voltage, the sensor adds to the CPU signal, and makes the CPU signal higher.

## TEST

- \_\_\_\_g. The raising and lowering of the signal voltage across the .45v reference signal creates "cross-counts" which indicate sensor activity.
- \_\_\_\_h. A normal oxygen sensor should show approximately 5 to 8 cross-counts per second at engine idle.
- \_\_\_\_i. Troubleshooting an oxygen sensor requires a standard voltmeter with a minimum of 10 megohms impedance, because using a digital voltmeter will produce highly inaccurate readings.
3. Solve problems concerning O<sub>2</sub> sensor operating requirements by answering the following questions.
- a. Can the O<sub>2</sub> sensor operate properly at a cold temperature?  
Answer: \_\_\_\_\_
- b. What do some O<sub>2</sub> sensors have to help them maintain operating temperature?  
Answer: \_\_\_\_\_
- c. If an O<sub>2</sub> sensor malfunctions, what will it cause the CPU to do?  
Answer: \_\_\_\_\_
4. Complete statements concerning MAP sensors by circling the word(s) that best complete(s) each statement.
- a. Engines require different amounts of fuel for different ("**road**", "**load**") conditions.
- b. The engine parameter that indicates the amount of load on the engine is manifold vacuum:
- 1) At WOT the manifold vacuum is at its (**highest**, **lowest**), or zero inches of Mercury at sea level.
  - 2) During deceleration, manifold vacuum is at its (**highest**, **lowest**) level which is usually around 22 inches of Mercury at sea level.
- c. Vacuum produced by an engine at higher altitudes is (**less**, **more**) because the air is thinner.
- d. Some vehicles use a (**barometric**, **altimeter**) sensor to compensate for altitude change, and others combine the MAP and barometric sensors.
- e. MAP sensor voltage output is (**inversely**, **directly**) proportional to manifold vacuum, and as vacuum increases, voltage output decreases, so a high voltage reading would indicate WOT under heavy load, and a low voltage reading indicates normal throttle under minimum load.

## TEST

- f. The CPU receives MAP sensor (**digital, analog**) inputs, combines them with other inputs into digital information, and determines the amount of fuel and timing required for engine load conditions.
5. Solve problems concerning coolant temperature sensors by answering the following questions.
- a. Since a coolant sensor operates as a thermistor, what happens electrically as temperature goes up?
- Answer: \_\_\_\_\_
- b. On fuel injected engines, the coolant sensor tells the CPU when the engine is cold and needs more fuel, and to what function can this be compared to on a carbureted engine?
- Answer: \_\_\_\_\_
- c. What can weak coolant cause?
- Answer: \_\_\_\_\_
6. Complete statements concerning engine RPM inputs to the CPU by circling the word(s) that best complete(s) each statement.
- a. The burn time of the air:fuel mixture in an engine is relatively constant, so as engine RPM increases, the timing must be (**advanced, retarded**) in order to completely burn increased combustion gases.
- b. The input from the distributor to the CPU is called ("**distributor reference pulse, distributor signal**").
- c. Some computer systems use the CPU for all timing changes while other systems leave the centrifugal advance mechanism intact, but whatever the system, the CPU must know engine (**RPMS, temperature**) in order to command fuel/timing to meet engine requirements.
- d. Setting the base timing of the ignition system requires disabling CPU control of timing, and this is usually done by (**interrupting, checking**) the distributor reference to the CPU.
- e. The engine diagnostic (**code, procedure**) that identifies the distributor reference signal is essential to CPU diagnostics.
- f. Distributor signals (**may be analog or digital, are always analog**).

## TEST

7. Select true statements concerning crankshaft position sensors by placing an "X" beside each statement that is true.

- \_\_\_\_\_a. When an ignition system does not use a distributor, the CPU receives the engine RPM reference from a crankshaft position sensor.
- \_\_\_\_\_b. The "crank sensor" is a transistor switch that outputs digital signals that are either ON or OFF.
- \_\_\_\_\_c. In a four cycle engine, the crankshaft rotates twice for every single crankshaft rotation, and the CPU needs to know when the piston is coming up on a compression stroke or an exhaust stroke, and this is accomplished with a camshaft sensor.
- \_\_\_\_\_d. In systems with no distributors, the CPU saturates the coil pack, and fires the secondary ignition voltage at just the right time for combustion, and the base reference for ignition timing comes from the cam/crank sensor.
- \_\_\_\_\_e. Should the cam/crank sensor or the CPU fail, a system without a distributor needs protection from engine mechanical damage, and this is accomplished with a knock sensor.
- \_\_\_\_\_f. The knock sensor counts how many times engine detonation happens in a given period, and if detonation is severe enough, the CPU will retard ignition timing.
- \_\_\_\_\_g. Early systems had all or nothing detonation protection that would retard timing a set amount when severe detonation was experienced, but newer systems vary the amount of spark retard in relation to the detonation counts made by the CPU.
- \_\_\_\_\_h. Generally, the CPU will retard ignition up to a maximum of 20 degrees from standard settings.
- \_\_\_\_\_i. On engines without distributors, anti-knock sensors are standard equipment, and the anti-knock sensors are also on some engines with distributors.

8. Solve problems concerning the TPS by answering the following questions.

- a. What does the CPU use TPS input for:

Answer: \_\_\_\_\_

- b. The CPU uses TPS input to prevent stalling at closed throttle, but how does the CPU use TPS input for wide open throttle?

Answer: \_\_\_\_\_



## TEST

9. Select true statements concerning MAT sensors by placing an "X" beside each statement that is true.
- \_\_\_\_\_ a. When a MAT sensor is used on a fuel-injected engine, its input is used by the CPU to enrich the fuel mixture when the engine is cold.
- \_\_\_\_\_ b. Less common fuel injection systems use a mass/density fuel control calibration which uses MAT sensor, MAP sensor, and TPS inputs to calculate the volume of air entering the engine, and the CPU then determines the amount of fuel required.
10. Complete statements concerning MAF sensors by circling the word(s) that best complete(s) each statement.
- a. With (**port fuel, standard**) injection systems, the amount of air coming into the engine must be monitored for best performance, and this is usually accomplished by a MAF sensor.
- b. The MAF sensor is capable of compensating for differences in (**altitude and humidity, speed and temperature**).
- c. Depending on type, the MAF sensor has a heat grid or wire which is kept at 75°C above the temperature of (**incoming air, the engine**).
- d. The mass of air entering the engine is determined by measuring the (**electrical load, fuel consumption**) required to keep the MAF sensor at its present temperature.
- e. As air crosses the grid, it cools the grid, causing the MAF relay to supply (**more, less**) electricity to the grid to maintain the 75°C temperature.
- f. The greater the electrical load at the MAF sensor, the (**more, less**) air there is entering the intake manifold.
- g. The MAF system does not measure the cubic feet of air because that would change with altitude and humidity, instead, the MAF measures actual air (**density, speed**) or mass of air.
- h. The electrical power requirement for the MAF is converted into a (**analog, digital**) signal to the CPU, and is in the range of 30 Hz to 150 Hz, with the higher frequency indicating a larger mass of air.
- i. The diagnostic readout for the MAF sensor parameter is in (**grams of air per second, cubic feet per second**).

## TEST

11. Solve problems concerning input sensor interaction by answering the following questions.
- a. How does a CPU indicate a driveability complaint?  
Answer: \_\_\_\_\_
- b. If a throttle position sensor fails, what would happen on deceleration, would the CPU deliver too much fuel, or not enough fuel?  
Answer: \_\_\_\_\_
- c. In most cases, what will a hard failure do to the CPU?  
Answer: \_\_\_\_\_
12. Complete statements concerning system output controls by circling the word(s) that best complete(s) each statement.
- a. Hot or cold, when an engine is first started, it is in an (**open loop, closed loop**) control mode, and the CPU uses the parameters in the PROM "look-up" table or chart to calculate appropriate outputs for the engine.
- b. For the engine to go into a closed loop mode, several things have to happen:
- 1) The O<sub>2</sub> sensor must be warmed up to approximately (**600°F, 200°F**).
  - 2) The CPU (**timer, distributor reference**) which allows the engine to stabilize before entering closed loop operation, must expire in order to avoid irregularities in engine performance.
  - 3) All other sensors must be sending valid data to the CPU, and although the CPU can obtain closed loop status if some sensors malfunction, the CPU will generally not allow closed loop operation if the (**CPU warning light is on, O<sub>2</sub> sensor is too cold**).
- c. While in the closed loop mode, the CPU receives (**continuing, intermittent**) input data from all sensors so it can evaluate conditions and determine the correct amount of fuel and timing necessary to obtain optimum emissions control and engine performance.
- d. During (**closed loop, open loop**) operation, the CPU controls most emissions systems like the evaporative charcoal cannister purging, air pump diversion to needed areas, and EGR vacuum.



## TEST

13. Solve problems concerning pulse width and on time functions by answering the following questions.

- a. A CPU controls fuel distribution at the rate of 10 cycles per second, and one complete cycle is called a pulse, but what is the length of a pulse,  $\frac{1}{100}$ th of a second of  $\frac{1}{10}$ th of a second?

Answer: \_\_\_\_\_

- b. The amount of time that a CPU commands fuel delivery has a specific name, what is it?

Answer: \_\_\_\_\_

14. Select true statements concerning fuel control systems by placing an "X" beside each statement that is true.

- \_\_\_\_\_ a. On a carbureted fuel system, the CPU controls the pulse width of the fuel control solenoid, and when the solenoid is energized, metering rods in the primary metering jets are drawn downward to allow more fuel to pass by the jet and enrich the air:fuel ratio.
- \_\_\_\_\_ b. Fuel injected systems are either throttle mounted or manifold mounted, and both system use an electric fuel pump to supply pressurized fuel at the injector whenever the engine is running.
- \_\_\_\_\_ c. The electrical relay that supplies power to the fuel pump has a built-in timer which prevents the pump from running more than a few seconds if the CPU does not receive an engine RPM signal.
- \_\_\_\_\_ d. When the CPU energizes the solenoid inside the injector itself, the injector plunger is drawn up off its seat, and this allows the pressurized fuel to discharge.
- \_\_\_\_\_ e. When the CPU de-energizes the solenoid inside the injector itself, the injector plunger reseats and stops fuel flow.
- \_\_\_\_\_ f. The fuel discharged from the tip of an injector gives a fine atomized spray that is close to as good as any carburetor can provide.
- \_\_\_\_\_ g. Throttle mounted injectors spray atomized fuel on top of the throttle plate where the throttle plate opening regulates the fuel mist/air mixture into the intake manifold plenum, and on into the combustion chamber.
- \_\_\_\_\_ h. Manifold port injectors are located in the intake manifold itself, and they spray atomized fuel directly on top of the intake valve in the cylinder head, and the injector is turned on/off by CPU command.

## TEST

- \_\_\_\_i. The throttle body of a manifold port injected system delivers an air:fuel mixture while the throttle mounted and carbureted systems deliver only air.
- \_\_\_\_j. Some manifold port injected systems use a cold start injector, and this injector is controlled by timers and relays to insure that it supplies fuel only for cold driveability requirements.
15. Solve problems concerning ignition spark timing control by answering the following questions.
- a. What do most basic CPU controlled ignition timing systems use that would be considered conventional?
- Answer: \_\_\_\_\_
- b. What happens with emissions control when a CPU controls timing?
- Answer: \_\_\_\_\_
- c. What kind of device is a crank sensor?
- Answer: \_\_\_\_\_
- d. Anti-knock sensors provide a system that retards timing in 2 degree intervals; what does this accomplish?
- Answer: \_\_\_\_\_
16. Select true statements concerning EGR controls by placing an "X" beside each statement that is true.
- \_\_\_\_a. All EGR valves route burned exhaust gases from the exhaust stream into the intake manifold to mix with the air:fuel mixture, and that is how EGRs reduce harmful NO<sub>x</sub>.
- \_\_\_\_b. Another important EGR function is that it lowers particulate matter and helps eliminate ignition detonation.
- \_\_\_\_c. EGR valves are vacuum controlled, and one type is connected to a ported vacuum while the other type is controlled by a CPU and a vacuum control valve that is pulse width modulated.
- \_\_\_\_d. Some EGR systems have a thermal switch in the cooling system to block vacuum to the EGR valve when the engine is cold.
- \_\_\_\_e. Some systems use a vacuum delay valve which allows the engine to reach a higher RPM before the EGR valve goes into operation, and the transition to EGR operation is smoother.

## TEST

- \_\_\_\_\_f. Because the CPU controls the pulse width of the vacuum valve, CPU controlled systems have finer control of EGR valve input, and provide extremely smooth transition because the vacuum from the vacuum valve to the EGR valve is precisely controlled.
- \_\_\_\_\_g. Even finer transition control is provided by the vent in the vacuum valve, because the CPU can command a quick drop in vacuum output to the EGR valve.

17. Complete statements concerning emission control devices by circling the word(s) that best complete(s) each statement.

- a. The **(CPU controlled engine, electronic fuel injection)** was developed in response to federal legislation designed to reduce harmful pollutants in exhaust emissions.
- b. Keeping the air:fuel ration at an optimum of **(15.1:1, 14.7:1)** helps control emissions, but the CPU controls other devices that also help clean the exhaust stream.
- c. The CPU controls the air supply to **(both functions, only one function)** in a dual bed catalytic converter.
- d. Air flow controlled by the CPU is supplied by an air pump through electrically controlled diverter valves which direct air to either one of the two beds or vents air to the **(atmosphere, exhaust system)**.
- e. The beds contain **(the same, different)** materials, and while one bed may require extra oxygen to work effectively, the other may work best with less oxygen.
- f. The CPU controls the hydraulic circuit that locks the torque converter turbine shaft to the cover, and this saves 3 to 4% slippage that occurs at highway speeds, improves fuel economy, and contributes to **(cleaner exhaust, smoother riding)**.
- g. Most late model vehicles have some sort of evaporative control system to keep **(fuel vapors, carbon)** from escaping into the atmosphere.
- h. Most evaporative system employ a charcoal cannister that stores the vapors until they can be purged back into the **(intake, exhaust)** system and burned.
- i. The CPU **(may be used, is never used)** to control a purge valve on a charcoal cannister.

## TEST

(NOTE: If the following activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

18. Demonstrate the ability to:
  - a. Test oxygen sensor operations. (Job Sheet #1)
  - b. Test MAP sensor operations. (Job Sheet #2)
  - c. Test engine coolant temperature sensor operations. (Job Sheet #3)
  - d. Test TPS operations. (Job Sheet #4)
  - e. Test EGR valve operations. (Job Sheet #5)
  - f. Adjust ignition timing. (Job Sheet #6)

## COMPUTERIZED ENGINE CONTROLS UNIT VIII

### ANSWERS TO TEST

- |    |    |    |    |    |    |    |    |   |
|----|----|----|----|----|----|----|----|---|
| 1. | a. | 7  | e. | 1  | i. | 10 | m. | 5 |
|    | b. | 11 | f. | 9  | j. | 4  |    |   |
|    | c. | 13 | g. | 2  | k. | 3  |    |   |
|    | d. | 8  | h. | 12 | l. | 6  |    |   |
2. c, d, f, g, h
3. a. No  
b. Internal electric heaters  
c. Stay in open loop
4. a. Load  
b. 1) Lowest  
2) Highest  
c. Less  
d. Barometric  
e. Inversely  
f. Analog
5. a. Resistance increases  
b. The choke function  
c. Erroneous sensor readings
6. a. Advanced  
b. Distributor reference pulse  
c. RPMs  
d. Interrupting  
e. Code  
f. May be analog or digital
7. a, c, d, e, f, g, h, i
8. a. To determine fuel and ignition timing requirements  
b. To improve performance
9. a, b

## ANSWERS TO TEST

10.
  - a. Port fuel
  - b. Altitude and humidity
  - c. Incoming air
  - d. Electrical load
  - e. More
  - f. More
  - g. Density
  - h. Digital
  - i. Grams of air per second
11.
  - a. With a CPU warning light
  - b. Too much fuel
  - c. Put it into a limp home mode
12.
  - a. Open loop
  - b.
    - 1) 600°F
    - 2) Timer
    - 3) CPU warning light is on
  - c. Continuing
  - d. Closed loop
13.
  - a. 1/10th
  - b. On time or duty cycle
14. a, b, c, d, e, g, h, j
15.
  - a. A vacuum advance diaphragm
  - b. Emissions control is better
  - c. A hall effect switch
  - d. Smooth, safe engine control that prevents piston damage
16. a, c, d, e, f, g
17.
  - a. CPU controlled engine
  - b. 14.7:1
  - c. Both functions
  - d. Atmosphere
  - e. Different
  - f. Cleaner exhaust
  - g. Fuel vapors
  - h. Intake
  - i. May be used
18. Job sheets evaluated according to criteria in the practical tests



## DIAGNOSTIC CODES AND TROUBLESHOOTING UNIT VIII

### UNIT OBJECTIVE

After completion of this unit, the student should be able to discuss guidelines for troubleshooting automotive computer systems, and the preparations preliminary to computer system troubleshooting. The student should also be able to discuss diagnostic code meanings for Chrysler, General Motors, and Ford vehicles, and retrieve diagnostic codes from selected vehicles. These competencies will be evidenced by correctly performing the procedures outlined in the assignment and job sheets, and by scoring a minimum of 85 percent on the unit test.

### SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms related to diagnostic codes and troubleshooting with their correct definitions.
2. Select true statements concerning troubleshooting guidelines.
3. Complete statements concerning troubleshooting lean/rich fuel conditions.
4. Select true statements concerning troubleshooting trees.
5. Complete statements concerning guidelines for testing wiring.
6. Complete statements concerning retrieving Chrysler diagnostic codes.
7. Complete statements concerning retrieving General Motors diagnostic codes.
8. Complete statements concerning retrieving Ford diagnostic codes.
9. Solve problems concerning hand held scanning devices.
10. Complete statements concerning guidelines for using hand held scanners.
11. Solve problems concerning code setting parameters.
12. Complete statements concerning code storage and retrieval.

**OBJECTIVE SHEET**

13. Identify operational systems and sensors, and list diagnostic codes for a Chrysler vehicle. (Assignment Sheet #1)
14. Identify operational systems and sensors, and list diagnostic codes for a General Motors vehicle. (Assignment Sheet #2)
15. Identify operational systems and sensors, and list diagnostic codes for a Ford vehicle. (Assignment Sheet #3)
16. Demonstrate the ability to:
  - a. Retrieve Chrysler diagnostic codes manually, and with a scanner. (Job Sheet #1)
  - b. Retrieve General Motors diagnostic codes manually, and with a scanner. (Job Sheet #2)
  - c. Retrieve Ford diagnostic codes manually, and with a scanner. (Job Sheet #3)



## DIAGNOSTIC CODES AND TROUBLESHOOTING UNIT VIII

### SUGGESTED ACTIVITIES

- A. Provide students with objective sheet.
- B. Provide students with information sheet.
- C. Make transparencies.
- D. Discuss unit and specific objectives.
- E. Discuss information sheet.
- F. Discuss and demonstrate the procedures outlined in the job sheets.
- G. Arrange for vehicles and appropriate service manuals so job sheets will reflect realworld troubleshooting and diagnostic code retrieval.
- H. Give test.

### REFERENCES USED IN DEVELOPING THIS UNIT

- A. *Tools and Techniques, Chrysler Computerized Engine Controls Through 1985.* Owatona, MN 55060: Mitchell Information Services, Inc., 1985.
- B. *Tools and Techniques, Ford MCU and EEC-IV, Computerized Engine Controls Through 1985.* Owatona, MN 55060: Mitchell Information Services, Inc., 1985.
- C. *Tools and Techniques, General Motors Computerized Engine Controls Through 1985.* Owatona, MN 55060: Mitchell Information Services, Inc., 1985.
- D. *1987 Service Manual, Electrical, Fuel, & Emissions, Front Wheel Drive Car, Omni/Charger, Horizon/Turismo, Aries, Reliant, Daytona, LeBaron, New Yorker, 600, Caravelle, Lancer, LeBaron GTS, Shadow, Sundance.* Highland Park, MI 48203: Chrysler Corporation, 1986.
- E. *1988 Chevrolet Camaro Service Manual.* Detroit, MI: General Motors Corporation, 1987.
- F. *1988 Ford Car Shop Manual, Body/Chassis/Electrical, Taurus/Sable.* Dearborn, MI 48121: Ford Motors Company, 1987.

## DIAGNOSTIC CODES AND TROUBLESHOOTING UNIT VIII

### INFORMATION SHEET

#### I. Terms and definitions

- A. AIS (automatic air speed) — The CPU control signal to the automatic air speed motor to increase or decrease the metered air flow allowed to pass by to control idle speed
- B. ASD (automatic shutdown) — A relay that will stop power supply to the fuel pump and the ignition module if the CPU doesn't detect a distributor reference pulse
- C. CALPAC — A trade name for the operational parameters stored in the PROM chip used on General Motors fuel injected engines
- D. Hard code — A diagnostic trouble code that indicates a current problem, but will reset after clearing codes and road testing
- E. PFI (port fuel injection) — An engine design that supplies fuel to each cylinder with injector discharge directly into the cylinder through, usually, the top of the intake valve
- F. SFI (sequential fuel injection) — The GM name for a fuel injection system that does not use a distributor
- G. Soft code — A diagnostic trouble code that indicates an intermittent problem, and will not reset during road testing
- H. Throttle body injection — An engine configuration that locates the fuel injector nozzles in a central air inlet to the intake manifold plenum

#### II. Troubleshooting guidelines

- A. One of the most common mistakes when diagnosing a computer controlled engine complaint is to assume that the computer system is the cause.
- B. The first thing that a good technician does is to verify that the engine and related systems are mechanically sound and this can be done with a simple cylinder leakage test.
- C. Visually inspect the wiring and vacuum routing; most new vehicles will have a vacuum routing diagram under the hood.
- D. Another excellent test for engine condition is to check engine vacuum while the starter is cranking, and again with the engine running.

## INFORMATION SHEET

- E. Be certain that the fuel being used doesn't have lead in it, and if you see that the owner has enlarged the fuel tank inlet, you can be pretty sure there is lead in the fuel.
- F. When a leaded fuel problem is suspected, use a lead detection kit, pull a sample from the fuel system, and inspect as directed.
- G. A simple compression check can often indicate the cause of a driveability complaint, and a cylinder balance test may also help identify problems.
- H. Make sure the engine oil has not been contaminated by gasoline by removing the PVC valve, and allowing the engine to pull fresh air into the system; if engine performance changes significantly, contaminated oil may be a problem.

### III. Troubleshooting lean/rich fuel conditions

- A. It often helps to know if an engine is running rich or lean, and since rich and lean fuel problems can sometimes seem identical, troubleshooting demands special techniques.
- B. If the engine will not start, check for fuel by operating the accelerator pump manually, or by using an injector triggering device if it's a fuel injected engine.
- C. If fuel is present, check to see if the engine is flooded by pressing the accelerator pedal to the floor and cranking the engine, and if the choke unloader is properly adjusted, this should clear a carbureted engine.
- D. On fuel injected engines, the CPU will go into a "clear flood" mode when it sees WOT (wide open throttle), and engine RPM input below normal idle (indicating cranking RPM).
- E. In clear flood mode, the CPU stops the injector trigger impulses, and delivers no fuel until the engine starts.
- F. If the engine will run, use an infrared exhaust analyzer to test for lean or rich fuel problems.

**EXAMPLE:** If the infrared analyzer reads high hydrocarbons (400 parts per million or higher), then the engine is not burning all the fuel that's entering the cylinder.

- G. High amounts of unburned fuel coming from the exhaust can be caused by:
  1. Too much fuel entering the system.
  2. An ignition system miss-fire which doesn't completely burn a normal amount of fuel.

## INFORMATION SHEET

- E. Another excellent way to check a lean/rich condition is to measure the oxygen sensor voltage:

1. High voltage indicates a rich fuel mixture.
2. Low voltage indicates a lean fuel mixture.

### IV. Troubleshooting trees (Transparency 1)

- A. Diagnostic trouble trees are extremely effective, but also confusing if a technician does not know how to read them properly.
- B. When directions require testing a sensor with a voltmeter, it is usually implied that jumper wires need to be placed in the circuit so that the sensor is left operational.

(NOTE: Jumper leads allow access to otherwise sealed circuits.)

- C. Most trouble trees use a cut-off point where a technician must make a decision to branch or not.

EXAMPLE: For testing a sensor, the trouble tree may say to check the voltage across two terminals, and if the voltage is above 5.0 volts, replace the sensor, and if voltage is below 4.0 volts, check wiring to the CPU; if the wiring is okay, replace the CPU.

- D. Voltage (in the example above) refers to system voltage sent to the sensor from the CPU, and while voltage between 4 and 5 volts would be considered normal, a voltage around 12 volts (battery voltage) would indicate that the CPU is not sending the correct system voltage to the sensor.

(NOTE: Don't make a hasty decision because the voltage was one or two tenths above or below the stated cut-off voltage; always think of what the test is trying to determine.)

- E. Before assuming that the CPU is at fault, always check the wiring between the CPU and the sensor.

EXAMPLE: A bare sensor wire that short circuits to a bare wire which is carrying battery voltage would indicate high voltage at the sensor. It would be easy to jump to the conclusion that the CPU was sending the sensor a voltage reference that is too high, and therefore the CPU is defective, but the fact is that the CPU is not at fault.

## INFORMATION SHEET

- F. When diagnosing CPU system problems, remember two important approaches:

1. Use common sense.
2. Work through the possibilities.

### V. Guidelines for testing wiring

- A. Loose connectors or shorts to ground under brackets or mounts can sometimes be found by performing a "wiggle" test and watching your test meter for changes that would indicate a wiring problem.
- B. Another helpful test is to use a redundant ground for a suspected bad circuit; that means inserting another ground in the circuit to compensate for corroded or loose connectors.

**(CAUTION: be sure to remove a redundant ground after diagnosis.)**

- C. A CPU cannot identify a poor ground because sensors only send varying voltage drops to the CPU, and a poor ground serves to increase the voltage drop of the entire circuit.
- D. Other circuit problems occur where ground straps or mounting areas have been cleaned and painted because paint is a good insulator.
- E. Another common cause of lost ground integrity is coolant corrosion.
- F. Disconnect and reconnect at points where a ground problem is suspected.

### VI. Retrieving Chrysler diagnostic codes (1984 and later)

- A. Chrysler diagnostic codes can be retrieved by cycling the ignition key three times within five seconds, or using a hand-held scanner.
- B. When the key is cycled to retrieve codes, the red "POWER LOSS" light on the instrument panel will flash the code numbers.
- C. When a hand-held scanner is used, the scanner read-out shows the codes.
- D. The initial code which verifies that the system is operational, and capable of retrieving stored diagnostic codes is "88."
- E. The "END OF MESSAGE" code will always appear as the final code after all other fault codes have been displayed, and that code is "55."

## INFORMATION SHEET

- F. Since fault codes vary from model to model, it is important to consult the service manual for the specific vehicle you're working on.

(NOTE: Assignment Sheet #1, and Job Sheet #1 provide additional information and activities to help you better service Chrysler vehicles.)

### VII. Retrieving General Motors diagnostic codes

- A. General Motors diagnostic codes can be retrieved by grounding the ALDL connector or by plugging a hand-held scanner into the ALDL.

(NOTE: the ALDL is located under the dash on the driver's side.)

- B. General Motors diagnostic code retrieval starts with code "12" which indicates that the system is capable of retrieving and displaying stored codes, and a "CHECK ENGINE" or "SERVICE ENGINE SOON" light will flash to display the codes.

- C. The code "12" is not displayed when a scanner is used.

- D. After the code "12" flashes three times, the trouble codes will be displayed in ascending numerical order, and each code will be repeated three times before the next code is displayed.

- E. After all trouble codes have been displayed, code "12" will be repeated.

(NOTE: Assignment Sheet #2, and Job Sheet #2 provide additional information and activities to help you better service General Motors vehicles.)

### VIII. Retrieving Ford diagnostic codes

- A. Ford calls its CPU system a MCU (Microprocessor Control Unit) for 1981 and 1982 vehicles, but uses a fourth generation system for 1983 and later, a newer system called EEC IV (Electronic Engine Control, fourth generation).

- B. Ford diagnostic codes can be retrieved using an analog voltmeter and vacuum gauge, or with a hand held scanner.

- C. Ford codes are displayed only once, and after retrieval, the codes and the service manual guide a technician to a specific test or to a portion of a test required for correcting the problem.

- D. In the event of more than one trouble code, correct the problems in the order the codes are displayed.



## INFORMATION SHEET

- E. The Ford system displays codes only once, and if a code is missed, the procedure must be started over at the first step.

(NOTE: Assignment Sheet #3, and Job Sheet #3 provide additional information and activities to help you better service Ford vehicles.)

### IX. Hand held scanning devices

- A. Diagnostic codes are stored in the RAM portion of the CPU, and there are several different hand held diagnostic tools for retrieving those diagnostic codes from the CPU.
- B. Most hand held scanners begin their routines by asking the technician to answer vital questions about the type of vehicle, the year, the engine series, what computer system, (CCC, MCU, EFI, or other) is in the vehicle, and other set-up information critical to effective troubleshooting.
- C. When using a scanner, always remember that you are seeing a CPU output or command, and not necessarily the condition.

### X. Guidelines for using hand held scanners

- A. First, retrieve and record the codes that are stored in memory, erase the codes, and road test the vehicle through all ranges of operation to see if any of the codes reset.
- B. If a code doesn't reset after being cleared, it indicates a soft code or intermittent which requires a different diagnostic technique.

(NOTE: Most service manuals have a special section just for soft codes.)

- C. If a code does reset after being cleared and the vehicle road tested, it indicates a hard code or present failure, and these are the easiest problems to repair.
- D. When beginning the repair of multiple (soft and hard) codes, always start with the codes that indicate a PROM or CPU failure before proceeding to other codes.
- E. After repairing the CPU and PROM related problems, address each code in ascending order, unless otherwise instructed.

**EXAMPLE:** GM instructs technicians to repair CPU and PROM codes first, and then repair other codes in ascending order, but Ford instructions call for repairing the codes in the order they are displayed.

## INFORMATION SHEET

### XI. Code setting parameters

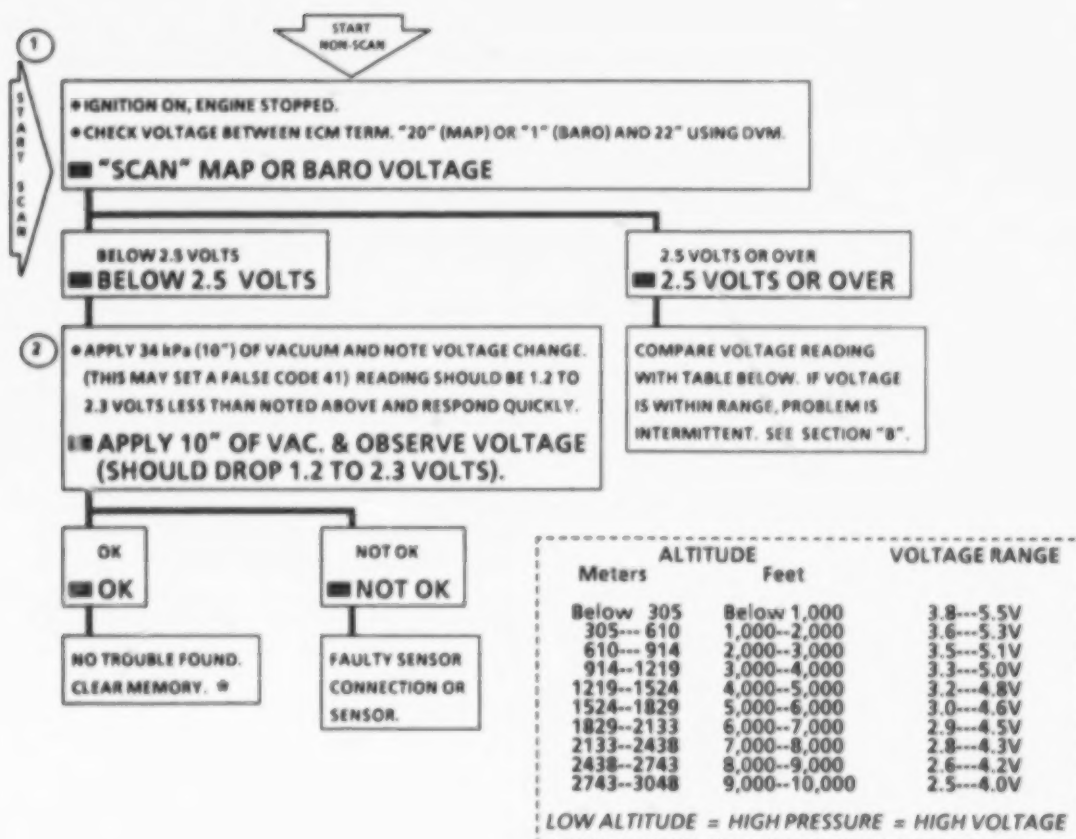
- A. In order for the CPU to set and store a code in long term memory, each sensor system must default in a specific way or sequence.
- B. For the oxygen sensor code to set:
  - 1. The engine has to run for at least 40 seconds.
  - 2. The coolant temperature has to be above 110°F.
  - 3. The CPU signal line voltage stays in a narrow voltage range of .35 to .55 volts.
  - 4. The TPS has to be over 1.0 volt output (over 6% throttle opening).
  - 5. All these conditions must stay true for 60 continuous seconds.
- C. For a coolant sensor too high code to set:
  - 1. The sensor output at the CPU has to be above 285°F (140°C).
  - 2. The engine has to have run for more than 20 seconds.
- D. For a VSS sensor code to set:
  - 1. The engine speed must be between 1500 and 4000 rpm.
  - 2. The MAP sensor must indicate an engine load.
  - 3. The gear selector must not be in PARK or NEUTRAL.
  - 4. All listed conditions must last for 20 continuous seconds.
- E. The CPU goes about testing for failure in different ways for different sensor circuits.  
 EXAMPLE: The pulse width modulated EGR control for GM vehicles is monitored as follows: the CPU waits until it sees steady MAP, TPS, and VSS sensor inputs to indicate level road and constant speed. The CPU then disables the EGR system, and looks for a rise in manifold vacuum to be indicated by the MAP sensor. If the MAP doesn't indicate a rise in vacuum, then the CPU disables the EGR one more time. If the MAP again fails to indicate a rise in vacuum, then code 53 is stored in long term memory, and the CHECK ENGINE light is turned on.
- F. An important thing to remember about code setting parameters is that knowing all the parameters that cause a sensor system to default provides a systematic guideline for troubleshooting.



# Troubleshooting Tree

"SCAN" STEP ONLY ■

## CHART C-1D MAP OR BARO OUTPUT CHECK 3.8L, 5.0L & 5.7L CARBURETED



\* RAPID VOLTAGE CHANGES CAN ONLY BE MEASURED WITH A DVM, SINCE A "SCAN" TOOL HAS A BUILT IN TIME DELAY.

CLEAR CODES AND CONFIRM "CLOSED LOOP" OPERATION AND NO "SERVICE ENGINE SOON" LIGHT.

Courtesy Chevrolet Motor Division, General Motors Corporation

## DIAGNOSTIC CODES AND TROUBLESHOOTING

### UNIT VIII

## ASSIGNMENT SHEET #1 — IDENTIFY OPERATIONAL SYSTEMS AND SENSORS, AND LIST DIAGNOSTIC CODES FOR A CHRYSLER VEHICLE

Directions: your instructor has selected a Chrysler vehicle for your evaluation. Use vehicle identification markings and the appropriate service manual to complete the information that follows.

### Vehicle Information

1. Make \_\_\_\_\_
2. Model \_\_\_\_\_ Year \_\_\_\_\_
3. CPU system used on engine: \_\_\_\_\_
4. Type of fuel system used on engine: \_\_\_\_\_
5. **Sensors on Vehicle**

[illegible]

(NOTE: Under "Diagnostic Code," list the code or codes that would indicate problems with the identified sensor.)

**ASSIGNMENT SHEET #1**

6. Expand on any code setting parameters indicated in the service literature: \_\_\_\_\_

---

---

---

7. **Service Manual Information**

Title of service manual: \_\_\_\_\_

---

Page numbers where your information was found: \_\_\_\_\_

---

8. Your name \_\_\_\_\_ Date: \_\_\_\_\_

☐ Have your instructor evaluate your information, and discuss your findings with your instructor.

(NOTE: Your instructor may direct you to complete Job Sheet #1 at this time.)

## DIASNOSTIC CODES AND TROUBLESHOOTING

### UNIT VIII

## ASSIGNMENT SHEET #2 — IDENTIFY OPERATIONAL SYSTEMS AND SENSORS, AND LIST DIAGNOSTIC CODES FOR A GENERAL MOTORS VEHICLE

Directions: your instructor has selected a General Motors vehicle for your evaluation. Use vehicle identification markings and the appropriate service manual to complete the information that follows.

### Vehicle Information

1. Make \_\_\_\_\_
2. Model \_\_\_\_\_ Year \_\_\_\_\_
3. CPU system used on engine: \_\_\_\_\_
4. Type of fuel system used on engine: \_\_\_\_\_
5. **Sensors on Vehicle**

[illegible]

(NOTE: Under "Diagnostic Code," list the code or codes that would indicate problems with the identified sensor.)

**ASSIGNMENT SHEET #2**

6. Expand on any code setting parameters indicated in the service literature: \_\_\_\_\_

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7. **Service Manual Information**

Title of service manual: \_\_\_\_\_

---

Page numbers where your information was found: \_\_\_\_\_

---

8. Your name \_\_\_\_\_ Date: \_\_\_\_\_

☐ Have your instructor evaluate your information, and discuss your findings with your instructor.

(NOTE: Your instructor may direct you to complete Job Sheet #2 at this time.)

## DIASNOSTIC CODES AND TROUBLESHOOTING

### ASSIGNMENT SHEET #3 — IDENTIFY OPERATIONAL SYSTEMS AND SENSORS, AND LIST DIAGNOSTIC CODES FOR A FORD VEHICLE

Directions: your instructor has selected a Ford vehicle for your evaluation. Use vehicle identification markings and the appropriate service manual to complete the information that follows.

### Vehicle Information

1. Make \_\_\_\_\_
2. Model \_\_\_\_\_ Year \_\_\_\_\_
3. CPU system used on engine: \_\_\_\_\_
4. Type of fuel system used on engine: \_\_\_\_\_
5. **Sensors on Vehicle**

[illegible]

(NOTE: Under "Diagnostic Code," list the code or codes that would indicate problems with the identified sensor.)

**ASSIGNMENT SHEET #3**

6. Expand on any code setting parameters indicated in the service literature: \_\_\_\_\_

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---

---

7. **Service Manual Information**

Title of service manual: \_\_\_\_\_

---

Page numbers where your information was found: \_\_\_\_\_

---

8. Your name \_\_\_\_\_ Date: \_\_\_\_\_

☐ Have your instructor evaluate your information, and discuss your findings with your instructor.

(NOTE: Your instructor may direct you to complete Job Sheet #3 at this time.)

## DIAGNOSTIC CODES AND TROUBLESHOOTING UNIT VIII

### JOB SHEET #1 — RETRIEVE CHRYSLER DIAGNOSTIC CODES MANUALLY, AND WITH A SCANNER

#### A. Tools and equipment

1. Chrysler vehicle as selected by instructor
2. Appropriate service manual
3. Basic hand tools
4. Scanner or Chrysler diagnostic readout tool
5. Jumper wire
6. Fender covers
7. Pencil
8. Safety glasses

#### B. Routine #1 — Retrieving Chrysler codes manually

1. Bring vehicle into shop area, open hood, and install fender covers.
2. Put on safety glasses.
3. Block drive wheels, and install exhaust removal system.
4. Open your service manual to the section on code retrieval.
5. Start the engine, and move the transmission selector through all positions, ending in PARK.
6. Turn the air conditioning switch ON, then OFF (if so equipped).
7. Stop the engine, and without starting the engine again, turn the ignition key ON, OFF, ON, OFF, and ON.
8. Watch for the diagnostic codes as they begin to flash on the POWER LIMITED lamp on the instrument panel. (Figure 1)



## JOB SHEET #1

FIGURE 1



9. Watch carefully because the light will pulse to indicate the digits in the code, and the pulse (or pulses) of the first digit will be separated from the pulse (or pulses) of the second digit by four seconds.
10. Write the diagnostic codes down for reference:

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---

☐ Have your instructor check your work.

11. Turn ignition OFF.
12. Refer to your service manual for proper repair sequence.

C. Routine #2 — Retrieving Chrysler codes with a scanner

1. Put on safety glasses.
2. Start the engine, and move the transmission selector through all positions, ending in PARK.
3. Turn the air conditioning switch ON, then OFF (if so equipped).
4. Stop the engine, and without starting the engine again, turn the ignition key ON, OFF, ON, OFF, and ON.
5. Attach the scanner or readout device as instructions indicate, and read the codes as they are displayed. (Figure 2)

## JOB SHEET #1

FIGURE 2



6. Write the diagnostic codes down for reference:
- \_\_\_\_\_
- \_\_\_\_\_
7. Compare your scanner readout with the codes you retrieved manually.
- ☐ Have your instructor check your work.
8. Refer to your service manual for proper repair sequence.
9. Turn ignition OFF, secure vehicle, and return tools and materials to proper storage.

## DIAGNOSTIC CODES AND TROUBLESHOOTING UNIT VIII

### JOB SHEET #2 — RETRIEVE GENERAL MOTORS DIAGNOSTIC CODES MANUALLY, AND WITH A SCANNER

A. Tools and materials

1. General Motors vehicle as selected by instructor
2. Appropriate service manual
3. Basic hand tools
4. Appropriate scanner
5. Fender covers
6. Pencil
7. Safety glasses

B. Routine #1 — Retrieving General Motors codes manually

(NOTE: The following routine is not for Cadillacs.)

1. Bring vehicle into shop area, open hood, and install fender covers.
2. Put on safety glasses.
3. Block drive wheels, and install exhaust removal system.
4. Open your service manual to the section on code retrieval.
5. Locate the ALDL connector.
6. Ground the wire indicated in the manual. (Figure 1)

FIGURE 1



## JOB SHEET #2

7. Turn the ignition key on, BUT DON'T START THE ENGINE.
8. Observe the CHECK ENGINE LIGHT (may be called SERVICE ENGINE SOON light).
9. Watch for the light to flash once, pause, then flash twice at a faster rate to indicate a code 12 which is always the first code displayed, and indicates the system is capable of displaying any stored codes.

(NOTE: If you don't get a code 12, check with your instructor.)

10. Observe carefully after the code 12 flashes for the CPU to flash other stored codes until all stored codes have been displayed (all codes are displayed three times).
11. Write down the codes as they are displayed: \_\_\_\_\_  
\_\_\_\_\_

12. Watch for code 12 to be displayed when all stored codes have been displayed; this indicates the cycle of stored codes has been completed, and will be run through again.

☐ Have your instructor check your work.

13. Refer to your service manual for proper repair sequence.

### C. Routine #2 — Retrieving General Motors codes with a scanner

1. Put on safety glasses.
2. Locate the ALDL connector, and plug scanner into the connector. (Figure 2)

FIGURE 2



## JOB SHEET #2

3. Turn ignition key on, BUT DON'T START THE ENGINE.
4. Follow scanner instructions for selecting year, model, engine, and other information.
5. Watch for diagnostic codes as they are displayed, but code 12 will not be shown by the scanner.
6. Write down the codes as they are displayed:

---

---

7. Follow service manual procedure for erasing codes.
8. Remove the scanner, and start the engine.
9. Road test the vehicle to see if the CHECK ENGINE light comes on.
10. Return vehicle to shop area, safely prepare it, and plug the scanner into the ALDL again.
11. Turn the ignition key on, BUT DON'T START THE ENGINE.
12. Watch for codes that reset, and write them down:\_\_\_\_\_

(NOTE: The codes that reset are called hard codes, and the codes that didn't reset are called soft codes or intermittent codes. In service work, you would begin to repair the hard codes first, which means that any PROM or ECM codes, 51 to 55, would be repaired first, the codes would be erased, and the vehicle road tested to see if other hard codes are valid problems.)

☐ Have your instructor check your work.

13. Refer to your service manual for proper repair sequence.
14. Secure vehicle, and return tools and materials to proper storage.

## DIAGNOSTIC CODES AND TROUBLESHOOTING UNIT VIII

### JOB SHEET #3 — RETRIEVE FORD DIAGNOSTIC CODES MANUALLY, AND WITH A SCANNER

#### A. Tools and materials

1. Ford vehicle as selected by instructor
2. Appropriate service manual
3. Basic hand tools
4. Analog voltmeter
5. Appropriate scanner
6. Jumper wires
7. Fender covers
8. Pencil
9. Safety glasses

#### B. Routine #1 — Retrieving Ford codes manually

1. Bring vehicle into shop area, open hood, and install fender covers.
2. Put on safety glasses
3. Block drive wheels, and install exhaust removal system.
4. Open your service manual to the section on code retrieval.
5. Start engine, allow vehicle to reach normal operating temperature, and turn ignition off.
6. Locate the self-test connector.
7. Insert a jumper ground between the tester ground and the self-test trigger.
8. Connect the positive lead of the analog voltmeter to the positive (+) post of the battery.

## JOB SHEET #3

9. Connect the negative lead of the voltmeter to the self-test output. (Figure 1)

FIGURE 1



10. Set the voltmeter to the 0 to 15 volt scale.
11. Turn the ignition key on, BUT DON'T START THE ENGINE.
12. Watch for diagnostic codes that will be displayed as needle pulses on the voltmeter.
13. Count the pulses, and watch for a two second delay between the first and second digits of the code.
14. Write down the codes: \_\_\_\_\_  
\_\_\_\_\_
15. Note that the throttle kicker retracts after all the codes have been displayed.  
☐ Have your instructor check your work.
16. Consult your service manual for proper repair sequence.
- C. Routine #2 — Retrieving Ford codes with a scanner
1. Put on safety glasses.
  2. Prepare the vehicle safely as outlined in Routine #1.
  3. Locate the self-test connector.

**JOB SHEET #3**

4. Plug the scanner into the connector. (Figure 2)

FIGURE 2



5. Turn the ignition on, BUT DON'T START THE ENGINE.
6. Follow the scanner instruction for selecting the year, model, engine, and other diagnostic set-up.
7. Read the codes as they are displayed on the scanner, and write them down: \_\_

---

☐ Have your instructor check your work.

8. Refer to your service manual for proper repair sequence.
9. Secure vehicle, and return tools and equipment to proper storage.



## DIAGNOSTIC CODES AND TROUBLESHOOTING UNIT VIII

### PRACTICAL TEST #1 JOB SHEET #1 — RETRIEVE CHRYSLER DIAGNOSTIC CODES MANUALLY, AND WITH A SCANNER

Student's name \_\_\_\_\_

Date \_\_\_\_\_

Evaluator's name \_\_\_\_\_

Attempt no. \_\_\_\_\_

Student instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

#### PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:

|                                                       | YES                         | NO                       |
|-------------------------------------------------------|-----------------------------|--------------------------|
| 1. Wore safety glasses.                               | 1. <input type="checkbox"/> | <input type="checkbox"/> |
| 2. Prepared vehicle safely.                           | 2. <input type="checkbox"/> | <input type="checkbox"/> |
| 3. Set up manual code retrieval properly.             | 3. <input type="checkbox"/> | <input type="checkbox"/> |
| 4. Recorded diagnostic codes.                         | 4. <input type="checkbox"/> | <input type="checkbox"/> |
| 5. Set up scanner code retrieval properly.            | 5. <input type="checkbox"/> | <input type="checkbox"/> |
| 6. Recorded diagnostic codes from scanner.            | 6. <input type="checkbox"/> | <input type="checkbox"/> |
| 7. Compared both code readings.                       | 7. <input type="checkbox"/> | <input type="checkbox"/> |
| 8. Secured vehicle, and returned tools and equipment. | 8. <input type="checkbox"/> | <input type="checkbox"/> |

Evaluator's comments: \_\_\_\_\_

 \_\_\_\_\_  
 \_\_\_\_\_

## JOB SHEET #1 PRACTICAL TEST

### PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another test procedure must be submitted for evaluation.)

Criteria:

| Tools and Equipment | Used Professionally<br>4 | Used Well<br>3           | Used Acceptably<br>2 | Used Improperly<br>1 |
|---------------------|--------------------------|--------------------------|----------------------|----------------------|
| Manual Retrieval    | Excellent<br>4           | Good<br>3                | Fair<br>2            | Poor<br>1            |
| Scanner Retrieval   | Excellent<br>4           | Good<br>3                | Fair<br>2            | Poor<br>1            |
| Safety              | Well Observed<br>4       | Acceptably Observed<br>3 | Poorly Observed<br>2 | Careless<br>1        |

EVALUATOR'S COMMENTS: \_\_\_\_\_

#### PERFORMANCE EVALUATION KEY

- 4 — Skilled — Can perform job with no additional training.
- 3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
- 2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
- 1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

## DIAGNOSTIC CODES AND TROUBLESHOOTING UNIT VIII

### PRACTICAL TEST #2 JOB SHEET #2 — RETRIEVE GENERAL MOTORS DIAGNOSTIC CODES MANUALLY, AND WITH A SCANNER

Student's name \_\_\_\_\_

Date \_\_\_\_\_

Evaluator's name \_\_\_\_\_

Attempt no. \_\_\_\_\_

Student instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

#### PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:

|                                                       | YES                         | NO                       |
|-------------------------------------------------------|-----------------------------|--------------------------|
| 1. Wore safety glasses.                               | 1. <input type="checkbox"/> | <input type="checkbox"/> |
| 2. Prepared vehicle safely.                           | 2. <input type="checkbox"/> | <input type="checkbox"/> |
| 3. Set up manual code retrieval properly.             | 3. <input type="checkbox"/> | <input type="checkbox"/> |
| 4. Recorded diagnostic codes retrieved.               | 4. <input type="checkbox"/> | <input type="checkbox"/> |
| 5. Road tested vehicle to reset codes.                | 5. <input type="checkbox"/> | <input type="checkbox"/> |
| 6. Set up scanner code retrieval properly.            | 6. <input type="checkbox"/> | <input type="checkbox"/> |
| 7. Recorded diagnostic codes from scanner.            | 7. <input type="checkbox"/> | <input type="checkbox"/> |
| 8. Secured vehicle, and returned tools and equipment. | 8. <input type="checkbox"/> | <input type="checkbox"/> |

Evaluator's comments: \_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

## JOB SHEET #2 PRACTICAL TEST

### PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another test procedure must be submitted for evaluation.)

Criteria:

| Tools and Equipment | Used Professionally<br>4 | Used Well<br>3           | Used Acceptably<br>2 | Used Improperly<br>1 |
|---------------------|--------------------------|--------------------------|----------------------|----------------------|
| Manual Retrieval    | Excellent<br>4           | Good<br>3                | Fair<br>2            | Poor<br>1            |
| Scanner Retrieval   | Excellent<br>4           | Good<br>3                | Fair<br>2            | Poor<br>1            |
| Safety              | Well Observed<br>4       | Acceptably Observed<br>3 | Poorly Observed<br>2 | Careless<br>1        |

EVALUATOR'S COMMENTS: \_\_\_\_\_

#### PERFORMANCE EVALUATION KEY

- 4 — Skilled — Can perform job with no additional training.
- 3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
- 2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
- 1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

# **DIAGNOSTIC CODES AND TROUBLESHOOTING UNIT VIII**

## **PRACTICAL TEST #3 JOB SHEET #3 — RETRIEVE FORD DIAGNOSTIC CODES MANUALLY, AND WITH A SCANNER**

Student's name \_\_\_\_\_

Date \_\_\_\_\_

Evaluator's name \_\_\_\_\_

Attempt no. \_\_\_\_\_

Student instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

### **PROCESS EVALUATION**

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:

|                                                       | YES                         | NO                       |
|-------------------------------------------------------|-----------------------------|--------------------------|
| 1. Wore safety glasses.                               | 1. <input type="checkbox"/> | <input type="checkbox"/> |
| 2. Prepared vehicle safely.                           | 2. <input type="checkbox"/> | <input type="checkbox"/> |
| 3. Located self-test connector.                       | 3. <input type="checkbox"/> | <input type="checkbox"/> |
| 4. Inserted jumper ground properly.                   | 4. <input type="checkbox"/> | <input type="checkbox"/> |
| 5. Completed manual code retrieval.                   | 5. <input type="checkbox"/> | <input type="checkbox"/> |
| 6. Recorded diagnostic codes.                         | 6. <input type="checkbox"/> | <input type="checkbox"/> |
| 7. Set up scanner code retrieval properly.            | 7. <input type="checkbox"/> | <input type="checkbox"/> |
| 8. Recorded diagnostic codes from scanner.            | 8. <input type="checkbox"/> | <input type="checkbox"/> |
| 9. Secured vehicle, and returned tools and equipment. | 9. <input type="checkbox"/> | <input type="checkbox"/> |

Evaluator's comments: \_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

## JOB SHEET #3 PRACTICAL TEST

### PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another test procedure must be submitted for evaluation.)

Criteria:

|                     |                          |                          |                      |                      |
|---------------------|--------------------------|--------------------------|----------------------|----------------------|
| Tools and Equipment | Used Professionally<br>4 | Used Well<br>3           | Used Acceptably<br>2 | Used Improperly<br>1 |
| Manual Retrieval    | Excellent<br>4           | Good<br>3                | Fair<br>2            | Poor<br>1            |
| Scanner Retrieval   | Excellent<br>4           | Good<br>3                | Fair<br>2            | Poor<br>1            |
| Safety              | Well Observed<br>4       | Acceptably Observed<br>3 | Poorly Observed<br>2 | Careless<br>1        |

EVALUATOR'S COMMENTS: \_\_\_\_\_

#### PERFORMANCE EVALUATION KEY

- 4 — Skilled — Can perform job with no additional training.
- 3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
- 2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
- 1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

## DIAGNOSTIC CODES AND TROUBLESHOOTING UNIT VIII

### TEST

NAME \_\_\_\_\_

SCORE \_\_\_\_\_

1. Match terms related to diagnostic codes and troubleshooting with their correct definitions.

- |                                                                                                                                                                      |                                   |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------|
| <p>_____a. The CPU control signal to the automatic air speed motor to increase or decrease the metered air flow allowed to pass by to control idle speed</p>         | <p>1. Hard code</p>               |
| <p>_____b. A relay that will stop power supply to the fuel pump and the ignition module if the CPU doesn't detect a distributor reference pulse</p>                  | <p>2. Soft code</p>               |
| <p>_____c. A trade name for the operational parameters stored in the PROM chip used on General Motors fuel injected engines</p>                                      | <p>3. SFI</p>                     |
| <p>_____d. A diagnostic trouble code that indicates a current problem, but will reset after clearing codes and road testing</p>                                      | <p>4. Throttle body injection</p> |
| <p>_____e. An engine design that supplies fuel to each cylinder with injector discharge directly into the cylinder through, usually, the top of the intake valve</p> | <p>5. AIS</p>                     |
| <p>_____f. The GM name for a fuel injection system that does not use a distributor</p>                                                                               | <p>6. CALPAC</p>                  |
| <p>_____g. A diagnostic trouble code that indicates an intermittent problem, and will not reset during road testing</p>                                              | <p>7. ASD</p>                     |
| <p>_____h. An engine configuration that locates the fuel injector nozzles in a central air inlet to the intake manifold plenum</p>                                   | <p>8. PFI</p>                     |

2. Select true statements concerning troubleshooting guidelines by placing an "X" beside each statement that is true.

- \_\_\_\_\_a. One of the best things to do when diagnosing a computer controlled engine complaint is to assume that the computer system is the cause.



## TEST

- \_\_\_\_\_b. The first thing that a good technician does is to verify that the engine and related systems are mechanically sound and this can be done with a simple cylinder leakage test.
  - \_\_\_\_\_c. Visually inspect the wiring and vacuum routing; most new vehicles will have a vacuum routing diagram in the glove compartment.
  - \_\_\_\_\_d. Another excellent test for engine condition is to check engine vacuum while the starter is cranking, and again with the engine running.
  - \_\_\_\_\_e. Be certain that the fuel being used doesn't have lead in it, and if you see that the owner has enlarged the fuel tank inlet, you can be pretty sure there is lead in the fuel.
  - \_\_\_\_\_f. When a leaded fuel problem is suspected, use a lead detection kit, pull a sample from the fuel system, and inspect as directed.
  - \_\_\_\_\_g. A simple compression check can often indicate the cause of a driveability complaint, and a cylinder balance test may also help identify problems.
  - \_\_\_\_\_h. Make sure the engine oil has not been contaminated by gasoline by removing the PVC valve, and allowing the engine to pull fresh air into the system; if engine performance changes significantly, contaminated oil may be a problem.
3. Complete statements concerning troubleshooting lean/rich fuel conditions by circling the word(s) that best complete(s) each statement.
- a. If often helps to know if an engine is running rich or lean, and since rich and lean fuel problems can sometimes seem (**identical, very different**), troubleshooting demands special techniques.
  - b. If the engine will not start, check for fuel by operating the (**accelerator pump, choke**) manually, or by using an injector triggering device if it's a fuel injected engine.
  - c. If fuel is present, check to see if the engine is flooded by pressing the accelerator pedal to the floor and cranking the engine, and if the choke unloader is properly adjusted, this should clear a (**carbureted engine, fuel injected engine**).
  - d. On fuel injected engines, the CPU will go into a "clear flood" mode when it sees WOT, and engine RPM input below normal (**idle, temperature**).
  - e. In clear flood mode, the CPU stops the injector trigger impulses, and delivers (**no fuel, fuel**) until the engine starts.
  - f. If the engine will run, use a(n) (**infrared exhaust analyzer, standard test kit**) to test for lean or rich fuel problems.



## TEST

- g. High amounts of unburned fuel coming from the exhaust can be caused by:
  - 1) Too much **(fuel, air)** entering the system.
  - 2) An ignition system **(miss-fire, delay)** which doesn't completely burn a normal amount of fuel.
- h. Another excellent way to check a lean/rich condition is to measure the oxygen sensor voltage:
  - 1) High voltage indicates a **(rich, lean)** fuel mixture.
  - 2) Low voltage indicates a **(rich, lean)** fuel mixture.

4. Select true statements concerning troubleshooting trees by placing an "X" beside each statement that is true.

(NOTE: For a statement to be true, all parts of the statement must be true.)

- \_\_\_\_a. Diagnostic trouble trees are extremely effective, and not confusing at all.
- \_\_\_\_b. When directions require testing a sensor with a voltmeter, it is usually implied that jumper wires need to be placed in the circuit so that the sensor will be disabled.
- \_\_\_\_c. Most trouble trees use a cut-off point where a technician must make a decision to branch or not.
- \_\_\_\_d. Voltage refers to system voltage sent to the sensor from the CPU, and while voltage between 4 and 5 volts would be considered normal, a voltage around 12 volts would indicate that the CPU is sending the correct system voltage to the sensor.
- \_\_\_\_e. Before assuming that the CPU is at fault, always check the wiring between the CPU and the sensor.
- \_\_\_\_f. When diagnosing CPU system problems, remember two important approaches:
  - 1) Use common sense.
  - 2) Work through the possibilities.

5. Complete statements concerning guidelines for testing wiring by circling the word(s) that best complete(s) each statement.
- a. Loose connectors or shorts to ground **(at connectors, under brackets or mounts)** can sometimes be found by performing a "wiggle" test and watching your test meter for changes that would indicate a wiring problem.

## TEST

- b. Another helpful test is to use a redundant ground for a suspected bad circuit; that means inserting another ground in the circuit to compensate for (**corroded or loose connectors, loose wires**).
  - c. A CPU cannot identify a poor ground because sensors only send varying voltage drops to the CPU, and a poor ground serves to (**increase, decrease**) the voltage drop of the entire circuit.
  - d. Other circuit problems occur where ground straps or mounting areas have been cleaned and painted because paint is a good (**insulator, conductor**).
  - e. Another common cause of (**overheating, lost ground integrity**) is coolant corrosion.
  - f. (**Disconnect and reconnect, Visually inspect**) at points where a ground problem is suspected.
6. Complete statements concerning retrieving Chrysler diagnostic codes by circling the word(s) or number(s) that best complete(s) each statement.
- a. Chrysler diagnostic codes can be retrieved by cycling the ignition key (**three, two**) times within five seconds, or using a hand-held scanner.
  - b. When the key is cycled to retrieve codes, the red ("**SERVICE ENGINE**", "**POWER LOSS**") light on the instrument panel will flash the code numbers.
  - c. When a hand-held scanner is used, the scanner read-out shows (**the codes, the problems by name**).
  - d. The initial code which verifies that the system is operational, and capable of retrieving stored diagnostic codes is ("**88**", "**99**").
  - e. The "END OF MESSAGE" code will always appear as the final code after all other fault codes have been displayed, and that code is ("**55**", "**66**").
  - f. Since fault codes vary from model to model, it is important to consult the service manual for the (**specific vehicle, general car line**) you're working on.
7. Complete statements concerning retrieving General Motors diagnostic codes by circling the word(s) or number(s) that best complete(s) each statement.
- a. General Motors diagnostic codes can be retrieved by (**reading, grounding**) the ALDL connector or by plugging a hand-held scanner into the ALDL.
  - b. General Motors diagnostic code retrieval starts with code "12" which indicates that the system is capable of retrieving and displaying stored codes, and a "CHECK ENGINE" or "SERVICE ENGINE SOON" light will (**stay on constantly, flash**) to display the codes.

## TEST

- c. The code "12" (**is not, is**) displayed when a scanner is used.
  - d. After the code "12" flashes three times, the trouble codes will be displayed in ascending numerical order, and each code will be repeated (**three times, twice**) before the next code is displayed.
  - e. After all trouble codes have been displayed, (**code "12" will be repeated, code "44" will be displayed**).
8. Complete statements concerning retrieving Ford diagnostic codes by circling the word(s) or number(s) that best complete(s) each statement.
- a. Ford calls its CPU system a MCU for 1981 and 1982 vehicles, but uses a fourth generation system for 1983 and later, a newer system called (**EEC IV, QUAD 4**).
  - b. Ford diagnostic codes can be retrieved by using (**an analog, a digital**) voltmeter and vacuum gauge, or with a hand-held scanner.
  - c. Ford codes are displayed (**only once, three times**), and after retrieval, the codes and the service manual guide a technician to a specific test or to a portion of a test required for correcting the problem.
  - d. In the event of more than one trouble code, correct the problems in the (**order the codes are displayed, engine controls**) first.
  - e. The Ford system displays codes only once, and if a code is missed, the procedure must be started over (**at the first step, with the previous code**).
9. Solve problems concerning hand-held scanning devices by answering the following questions.
- a. How do most hand-held scanners begin their routines?  
 Answer: \_\_\_\_\_  
 \_\_\_\_\_
  - b. What does scanner output indicate, an exact condition, or a CPU output or command?  
 Answer: \_\_\_\_\_
10. Complete statements concerning guidelines for using hand-held scanners by circling the word(s) that best complete(s) each statement.
- a. First, retrieve and record the codes that are stored in memory, erase the codes, and road test the vehicle (**through all ranges of operation, at slow speed**) to see if any of the codes reset.

## TEST

- b. If a code doesn't reset after being cleared, it indicates a **(hard, soft)** code or intermittent which requires a different diagnostic technique.
  - c. If a code does reset after being cleared and the vehicle road tested, it indicates a **(hard, soft)** code or present failure, and these are the easiest problems to repair.
  - d. When beginning the repair of multiple codes, always start with the codes that indicate a **(PROM or CPU, mechanical component)** failure before proceeding to other codes.
  - e. After repairing the CPU and PROM related problems, address each code in **(ascending, descending)** order, unless otherwise instructed.
11. Solve problems concerning code setting parameters by answering the following questions.
- a. What must happen for the CPU to set and store a code in long term memory?  
Answer: \_\_\_\_\_  
\_\_\_\_\_
  - b. Sensor systems default in different ways, but generally, all elements of a default must do what, respond to a certain temperature, or last for so much time?  
Answer: \_\_\_\_\_
  - c. What is the important thing to remember about code setting parameters?  
Answer: \_\_\_\_\_  
\_\_\_\_\_
12. Complete statements concerning code storage and retrieval by circling the word(s) that best complete(s) each statement.
- a. Self diagnostic codes are stored in **(RAM, ROM)** until they are retrieved.
  - b. The area of **(RAM, ROM)** where codes are stored is called "long term memory" because it keeps that data stored even when the ignition key is turned off.
  - c. When the correct code retrieval sequence is followed, the CPU's central processor goes to the address where the code is stored, and places the binary representation of the code on the **(address buss, scanner)**.
  - d. The **(central processor, buffer)** takes the code from the buss, and sends the output signal to the output device for display.

## TEST

(NOTE: if the following activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

13. Identify operational systems and sensors, and list diagnostic codes for a Chrysler vehicle, (Assignment Sheet #1)
14. Identify operational systems and sensors, and list diagnostic codes for a General Motors vehicle. (Assignment Sheet #2)
15. Identify operational systems and sensors, and list diagnostic codes for a Ford vehicle. (Assignment Sheet #3)
16. Demonstrate the ability to:
  - a. Retrieve Chrysler diagnostic codes manually, and with a scanner. (Job Sheet #1)
  - b. Retrieve General Motors diagnostic codes manually, and with a scanner. (Job Sheet #2)
  - c. Retrieve Ford diagnostic codes manually, and with a scanner. (Job Sheet #3)

## DIAGNOSTIC CODES AND TROUBLESHOOTING UNIT VIII

### ANSWERS TO TEST

1.   a.    5                   e.    8  
     b.    7                   f.    3  
     c.    6                   g.    2  
     d.    1                   h.    4
  
2.   b, d, e, f, g, h
  
3.   a.    Identical  
     b.    Accelerator pump  
     c.    Carbureted engine  
     d.    Idle  
     e.    No fuel  
     f.    An infrared exhaust analyzer  
     g.    1) Fuel  
           2) Miss-fire  
     h.    1) Rich  
           2) Lean
  
4.   c, e, f
  
5.   a.    Under brackets or mounts  
     b.    Corroded or loose connectors  
     c.    Increase  
     d.    Insulator  
     e.    Lost ground integrity  
     f.    Disconnect and reconnect
  
6.   a.    Three  
     b.    POWER LOSS  
     c.    The codes  
     d.    88  
     e.    55  
     f.    Specific vehicle
  
7.   a.    Grounding  
     b.    Flash  
     c.    Is not  
     d.    Three times  
     e.    Code "12" will be repeated

## ANSWERS TO TEST

8.
  - a. EEC IV
  - b. An analog
  - c. Only once
  - d. The order the codes are displayed
  - e. At the first step
  
9.
  - a. By asking the technician to answer vital questions about the type of vehicle, the year, engine system, etc.
  - b. A CPU output or command
  
10.
  - a. Through all ranges of operation
  - b. Soft
  - c. Hard
  - d. PROM or CPU
  - e. Ascending
  
11.
  - a. Each sensor system must default in a specific way or sequence
  - b. Last for so much time
  - c. Knowing the parameters provides a systematic guideline for troubleshooting
  
12.
  - a. RAM
  - b. RAM
  - c. Address buss
  - d. Central processor
  
13. Assignment Sheet #1 evaluated to the satisfaction of the instructor
  
14. Assignment Sheet #2 evaluated to the satisfaction of the instructor
  
15. Assignment Sheet #3 evaluated to the satisfaction of the instructor
  
16. Job sheets evaluated according to criteria in the practical tests



## **AUTOMOTIVE MICROPROCESSOR APPLICATIONS**

### **UNIT IX**

#### **UNIT OBJECTIVE**

After completion of this unit, the student should be able to discuss the diversity of microcomputer usage in contemporary vehicles, and relate specific system functions to operator comfort and safety. The student should also be able to identify Chrysler, General Motors, and Ford computer applications for operator comfort and safety. These competencies will be evidenced by correctly completing the procedures outlined in the assignment sheets, and by scoring a minimum of 85 percent on the unit test.

#### **SPECIFIC OBJECTIVES**

After completion of this unit, the student should be able to:

1. Match terms related to automotive microprocessor applications with their correct definitions.
2. Select true statements concerning dashboard functions.
3. Complete statements concerning anti-lock brake controls.
4. Solve problems concerning seat position controls.
5. Solve problems concerning electronic steering controls.
6. Select true statements concerning suspension controls.
7. Solve problems concerning keyless entry.
8. Select true statements concerning theft deterrent systems.
9. Solve problems concerning trip control/monitor systems.
10. Complete statements concerning cruise control.
11. Select true statements concerning electronic climate control.
12. Solve problems concerning voice alert systems.
13. Solve problems concerning other control systems.



**OBJECTIVE SHEET**

14. Identify Chrysler computer applications for operator comfort and safety. (Assignment Sheet #2)
15. Identify General Motors computer applications for operator comfort and safety. (Assignment Sheet #2)
16. Identify Ford computer applications for operator comfort and safety. (Assignment Sheet #3)

## **AUTOMOTIVE MICROPROCESSOR APPLICATIONS UNIT IX**

### **SUGGESTED ACTIVITIES**

- A. Provide students with objective sheet.
- B. Provide students with information and assignment sheets.
- C. Make transparencies.
- D. Discuss unit and specific objectives.
- E. Discuss information sheet.
- F. Invite a new car owner, or several of them, to talk to the class about devices on their automobiles that serve operators comfort and convenience.
- G. Invite an area dealer or service manager to talk to the class about special service requirements for system microprocessors.
- H. Carefully note the opening directions for the assignment sheets. Assignment Sheet #1 is from Chrysler's 1987 front wheel drive car service manual, Assignment Sheet #2 is from GM's 1988 Camaro service manual, and Assignment Sheet #3 is from Ford's 1987 Taurus/Sable service manual. If these manuals are unavailable for your students, modify the assignment sheets, and correct assignment sheet answers as required to reflect locally available material.
- I. Give test.

### **REFERENCES USED IN DEVELOPING THIS UNIT**

- A. *Specialized Electronic Training*. Warren, MI 48090: Product Service Training, General Motors Corporation, 1984.
- B. *Servicing Vehicle Electronic Instruments*. Dearborn, MI 48121: Ford Parts and Service Division, Training and Publications Department, 1985.
- C. *EECII EECIV 5-Day Technician Certification*. Dearborn, MI 48121: Ford Parts and Service Division, Training and Publications Department, 1985.
- D. *Electricity and Electronics Fundamentals*. Highland Park, MI 48203: Training Program Development Department, Chrysler Corporation, 1981.
- E. *1988 Ford Car Shop Manual, Body/Chassis/Electrical, Taurus/Sable*. Dearborn, MI 48121: Ford Motor Company, 1987.

## REFERENCES USED IN DEVELOPING THIS UNIT

- F. 1988 *Chevrolet Camaro Service Manual*. Detroit, MI: General Motors Corporation, 1987.
- G. 1987 *Service Manual, Electrical, Fuel, & Emissions, Front Wheel Drive Car, Omni/Charger, Horizon/Turismo, Aries, Reliant, Daytona, LeBaron, New Yorker, 600, Caravelle, Lancer, LeBaron GTS, Shadow, Sundance*. Highland Park, MI 48203: Chrysler Corporation, 1986.

## **AUTOMOTIVE MICROPROCESSOR APPLICATIONS UNIT IX**

### **INFORMATION SHEET**

#### **I. Terms and definitions**

- A. EIC (Electronic Instrument Cluster) — A dashboard-mounted digital read-out of vehicle speed and other function gauges such as fuel level, oil pressure, and engine temperature
- B. Stepper motor — An electric motor that takes digital input pulses, and converts that signal into a continuous sweeping output such as a speedometer needle
- C. VATS (Vehicle Anti-Theft System) — A protection system that disables the ignition system, and eventually the starter system if an incorrect key is used, or if a "hot wire" start is attempted
- D. VSS (Vehicle Speed Sensor) — A digital input signal to the CPU that is used to operate cruise control, speedometer readings, and torque converter lock-up systems

#### **II. Dashboard functions**

- A. In modern vehicles, engines are computer controlled, but computers also operate to enhance operator comfort and alert the operator to trouble.
- B. The most noticeable change in contemporary vehicle dashboards is the EIC (electronic instrument cluster), which uses bar graph representations and digital numerics where analog gauges were previously used.
- C. For eye appeal and reading ease, EIC bar graphs are lit by LEDs or by fluorescent back-lighting techniques.
- D. EIC operations are also aided by the CPU which supplies vehicle speed information to the VSS (vehicle speed sensor) buffer.
- E. The VSS buffer transmits data to the EIC so MPH can be determined and properly displayed.
- F. When systems use an electric analog speedometer, the conventional sweep needle is driven by stepper motors, and commands to the stepper motors come from the CPU through the speedometer buffer.
- G. Almost all EICs contain a warning light to alert the operator to problems with the CPU system.
- H. Some systems have maintenance reminder indicators that alert the operator to the need for service.

## INFORMATION SHEET

### III. Anti-lock brake controls

- A. There are several different types of anti-lock brake controls, and all of them use some degree of CPU control.
- B. Most systems have a wheel speed indicator constructed of a simple slip ring and an interruptor system that works with a magnetic field located periodically to send an impulse to the sensor.
- C. When the wheel stops turning, the signal to the sensor is interrupted, and brake fluid pressure to the disc caliper is pulsed until the wheel sensor indicates motion once again.
- D. Some light duty trucks use a rear wheel anti-lock brake system.
- E. Some advanced systems use a modification of the anti-lock brake system to control wheel slippage during acceleration, and this requires a complicated power train with variable torque capabilities.

### IV. Seat position controls

- A. In cases where a vehicle is driven by more than one person, the problem of repositioning the driver's seat has been solved with what is called the "memory" seat.
- B. The power seat adjustment system "remembers" the settings for the control motors that position the seat, and this permits drivers to quickly reposition the seat to their liking without having to go through several trial-and-error settings.
- C. Another operator comfort introduced by Mercedes Benz is the seat heater which warms the driver's seat as the engine warms up.

### V. Electronic steering controls

- A. Some systems have replaced the mechanical coupling between the steering wheel and the front wheels of the vehicle with an electronic coupling.
- B. Electronic coupling is accomplished with steering wheel sensors which register the amount of angular motion as the steering wheel is turned, and this data is sent to a computer which drives electric motors at each wheel to move the wheels the exact amount requested.
- C. A steering system which uses all four wheels to steer the vehicle will improve tire wear by reducing turning radius.
- D. Four-wheel steering eliminates the problem of two different turning radii by aiming the rear wheels in the track of the front wheels.

## INFORMATION SHEET

- E. Four-wheel steering uses conventional mechanical front steering with the addition of movement-indicating sensors, and the rear steering is controlled by a computer.

### VI. Suspension controls

- A. Many vehicles use suspension height devices that are filled or vented by small compressors that are controlled by a computer.
- B. Height sensors mounted on the frame of the vehicle monitor chassis position; if the body is low, the computer energizes the compressors, and air is pumped into the shocks to raise the body.
- C. When the body is riding too high, the compressors vent pressure from the shocks in order to lower the body.
- D. Drivers can control ride quality in some systems through driver-selected controls that change hydraulic valving characteristics in suspension support devices to make the ride more firm or softer.

### VII. Keyless entry

- A. Some vehicles use a keyless entry system that is really the equivalent of a combination lock, and the operator has to dial the right combination to unlock the door.
- B. The system was designed as a theft deterrent, but it has probably helped keep a few impaired drivers off the road, because after a predetermined number of attempts, the system is disabled for a length of time.

### VIII. Theft deterrent systems

- A. There are many different theft deterrent systems in the contemporary vehicles, but the most successful is the VATS (Vehicle Anti-Theft System) used on late model Corvettes.
- B. The VATS uses a resistor in the shank of the ignition key, and if the VATS module doesn't read the proper resistance, the ignition system is disabled, and there will be no secondary ignition to the spark plugs.
- C. If repeated attempts to start the car are made, the VATS module will disable the starter system to keep from running the battery down.
- D. Some entry deterrent systems are activated when the door jamb switch indicates an open door, and an alarm not properly reset; the horn sounds in repeated, short blasts, and the headlights flash on and off rapidly.
- E. Other anti-theft systems use a motion detector such as a liquid mercury switch that closes the alarm circuit when the vehicle is bumped or moved.

## INFORMATION SHEET

### IX. Trip control/monitor systems

- A. A basic trip monitor system is tied into a vehicle's speedometer and odometer through the VSS.
- B. A basic trip monitor system uses manual input of trip distance from which the computer will calculate the ETA (estimated time of arrival).
- C. ETA is calculated by averaging the last two minutes of vehicle speed, and then projecting that speed through the remainder of the distance:
  - 1. If average vehicle speed decreases, the ETA is increased.
  - 2. If average vehicle speed increases, the ETA is decreased.
- D. Some systems monitor fuel consumption, and supply calculator function keys for determining MPG during a trip, and some systems are tied into the CPU and fuel delivery system.
- E. Some monitor systems provide instant average fuel economy, average MPG since reset, and the distance the operator can drive before running out of fuel.
- F. The CPU provides information from the VSS and updates about the pulse widths of the fuel injectors to the trip control computer module.
- G. Almost all trip control/fuel monitor systems provide a digital readout for the operator, and some systems use this capability to also display diagnostic codes for technicians.

### X. Cruise control

- A. Most of the cruise control systems after 1984, are controlled by a computer, and are much more durable and reliable than the older transducer systems.
- B. The cruise control computer is tied into the VSS circuits of the CPU, and determines the amount of vacuum to be applied to the vacuum servo.
- C. The vacuum servo is attached to the throttle linkage, and opens and closes the throttle in varying amounts depending on the vacuum applied.
- D. Some cruise control systems allow the operator to control vehicle speed in increments of 1 mph.

(NOTE: This is the "step-up/step-down" GM cruise control system.)



## INFORMATION SHEET

### XI. Electronic climate control

- A. Instead of using mechanical devices to control air blending and distribution, many vehicles now use an electronic control module for the heater/air conditioning systems.
- B. Some systems use electrically controlled vacuum solenoids to add or bleed vacuum at various servos which control air output.
- C. The computer also controls air conditioning compressor cycling, and it is often tied into the CPU which can disable the A/C under wide open throttle operation.
- D. The CPU can also disable the A/C compressor during engine overheating to help reduce heat at the radiator.
- E. Some electronic systems still use a temperature lever for operator selection of passenger compartment temperature, but the lever is attached to a variable resistor or similar electronic device for computer input.
- F. Fully automatic climate control systems use an inside temperature sensing device to provide feedback to the computer so that fine tuning of temperature goes on all the time.

### XII. Voice alert systems

- A. Voice alert systems are optional, but are available on many vehicles, and almost all systems contain a voice module which when stimulated by certain conditions will provide a spoken warning message through the radio speaker.
- B. The control module will generally have a combination of phonetic sounds prerecorded and coded for retrieval, and the computer selects the sounds and the order required to provide the operator with an appropriate warning.
- C. Voice alert messages cover conditions ranging from engine overheating to doors that are ajar, and some systems have over 10 functions.
- D. For added safety, the voice control module can mute the radio speaker system to keep loud music from drowning out a warning message.
- E. Exported vehicles can be equipped with modules for different languages with alert messages spoken by a male or female voice.

### XIII. Other control systems

- A. Some vehicles use radio controls located in the center of the steering wheel spokes where switches using fiber optics transmit data to a slip-ring type connection on to a wiring harness that leads to an electronic radio receiver.



## INFORMATION SHEET

- B. From a model first shown in public in 1985, there is a guidance control system that uses information from a satellite to identify the vehicle on the ground, and track the vehicle's movements.
- C. The vehicle operator simply requests a visual output of vehicle location, and the satellite sends a coded signal to the CPU receiver, and the location is displayed on a CRT.
- D. For added operator convenience, the CRT can display the area map in several different sizes so that the operator can pinpoint immediate, observable landmarks.
- E. Some vehicles are equipped with an electronic eye that senses oncoming vehicles at night, and automatically dims the lights.
- F. Another system changes the rear view mirror from day to night viewing automatically when another vehicle approaches from the rear.
- G. Other systems control transmission shift points with electronic shift solenoids which control shift valves in the transmission, and provide smoother, more predictable operation.
- H. Nissan introduced a "Dopler Radar" system which warns an operator of a potential collision.
- I. Other vehicles have incorporated a system that will warn a driver that a tire is going flat.

## AUTOMOTIVE MICROPROCESSOR APPLICATIONS UNIT IX

### ASSIGNMENT SHEET #1 — IDENTIFY CHRYSLER APPLICATIONS FOR OPERATOR COMFORT AND SAFETY

Directions: Your instructor will provide you with a Chrysler 1987 front wheel drive car service manual suitable for this assignment. Open the manual, check the index, and locate the electrical section. Read through the section as required to answer the following questions:

1. What type gauges does the instrument panel have?

Answer: \_\_\_\_\_

2. In what position does the ignition switch have to be for the gauges to be accurate?

Answer: \_\_\_\_\_

3. What type of clock does the vehicle have?

Answer: \_\_\_\_\_

4. Where is the clock located?

Answer: \_\_\_\_\_

5. What type of displays are used in the electronic instrument clusters?

Answer: \_\_\_\_\_

6. What functions are displayed in the electronic instrument clusters?

Answer: \_\_\_\_\_

7. What makes the electronic clusters easy to distinguish from conventional clusters?

Answer: \_\_\_\_\_

8. How many functions are accomplished by the electronic voice alert system?

Answer: \_\_\_\_\_

9. What follows all voice alert messages?

Answer: \_\_\_\_\_

10. If the voice alert sound is too high, can the level be turned down, and if so, how?

Answer: \_\_\_\_\_

**ASSIGNMENT SHEET #1**

11. What controls alert messages that can be heard only when the vehicle is in forward motion?

Answer: \_\_\_\_\_

12. If you wanted to completely turn off the voice signal in the alert system, can it be done, and if so, how?

Answer: \_\_\_\_\_

13. What happens if there is an alert message while the voice is turned off?

Answer: \_\_\_\_\_

## **AUTOMOTIVE MICROPROCESSOR APPLICATIONS UNIT IX**

### **ASSIGNMENT SHEET #2 — IDENTIFY GENERAL MOTORS APPLICATIONS FOR OPERATOR COMFORT AND SAFETY**

Directions: Your instructor will provide you with a General Motors 1988 Camaro service manual suitable for this assignment. Open the manual, check the index, and locate the INSTRUMENT PANEL section. Read through the section as required to answer the following questions:

1. What supplies current to the instrument panel lights and instruments?

Answer: \_\_\_\_\_

2. What instruments are housed in the instrument panel?

Answer: \_\_\_\_\_  
\_\_\_\_\_

3. What position must the ignition switch be in for the fuel gauge to display an accurate reading?

Answer: \_\_\_\_\_

4. When the ignition switch is turned to START, why does the temperature warning light come on?

Answer: \_\_\_\_\_  
\_\_\_\_\_

5. If the generator warning light does not come on when the switch is turned ON, and the engine is not running, what does it indicate?

Answer: \_\_\_\_\_  
\_\_\_\_\_

6. When should the SERVICE ENGINE SOON light come on, and for how long?

Answer: \_\_\_\_\_  
\_\_\_\_\_

7. What types of speedometers are used in these GM vehicles?

Answer: \_\_\_\_\_

**ASSIGNMENT SHEET #2**

8. What drives a quartz speedometer?

Answer: \_\_\_\_\_

9. What types of displays do digital speedometers use?

Answer: \_\_\_\_\_

## AUTOMOTIVE MICROPROCESSOR APPLICATIONS UNIT IX

### ASSIGNMENT SHEET #3 — IDENTIFY FORD APPLICATIONS FOR OPERATOR COMFORT AND SAFETY

Directions: Your instructor will provide you with a Ford 1987 Taurus/Sable service manual suitable for this assignment. Open the manual, check the index, and locate the section that covers Instruments, Clusters, Controls, and Warning Systems. Read through the section as required to answer the following questions:

1. What does the Taurus standard instrument cluster contain?

Answer: \_\_\_\_\_  
\_\_\_\_\_

2. What type of gauges are used for fuel and temperature?

Answer: \_\_\_\_\_

3. How many modules are in the electronic instrument cluster, and what systems do they serve?

Answer: \_\_\_\_\_  
\_\_\_\_\_

4. What position does the ignition have to be in for the electronic cluster to be operational?

Answer: \_\_\_\_\_

5. How do the electronic displays of the modules prove out when the ignition is first turned from the OFF to the RUN position?

Answer: \_\_\_\_\_  
\_\_\_\_\_

6. How would an operator switch the speedometer readout from miles per hour to a metric readout?

Answer: \_\_\_\_\_

7. What does the DTE button display?

Answer: \_\_\_\_\_

**ASSIGNMENT SHEET #3**

8. Is there a maximum speed the digital speedometer will indicate, and if so, what is it?

Answer: \_\_\_\_\_

9. How does the speed alarm alert the driver that he/she is going faster than the preset speed?

Answer: \_\_\_\_\_

\_\_\_\_\_

10. What three things will the fuel computer calculate and display?

Answer: \_\_\_\_\_

\_\_\_\_\_

11. Does the fuel computer display in miles per gallon or liters per kilometer?

Answer: \_\_\_\_\_

12. List at least three messages the system scanner will display.

Answer: \_\_\_\_\_

\_\_\_\_\_

## **AUTOMOTIVE MICROPROCESSOR APPLICATIONS UNIT IX**

### **ANSWERS TO ASSIGNMENT SHEETS**

(NOTE: If service manuals other than those listed in the assignment sheets are used, these answers should be modified to reflect the change.)

#### **Assignment Sheet #1**

1. Magnetic
2. ON
3. Digital
4. With the radio
5. Vacuum fluorescent displays
6. Oil pressure, system voltage, engine temperature, fuel level, and speed and odometer readings
7. The displays are digital and linear
8. 11
9. A group of beeps and a tone
10. Yes, with a volume control
11. A distance sensor, and a backup lamp switch
12. Yes, by locating the ON/OFF switch on the top right in the glove compartment, and switching it to the rear of the vehicle
13. All warning lamps and tones continue to work normally

#### **Assignment Sheet #2**

1. Printed circuits
2. Fuel gauge, temperature indicator light, generator light, and speedometer
3. ON or ACCESSORY
4. To indicate whether the light is functioning properly
5. Either the bulb is burned out, or the wiring to the generator has an open circuit
6. Should come on during engine starting, and may stay on until a short time after the engine starts
7. Mechanical and electrical
8. A precision DC motor
9. Liquid crystal and vacuum tube fluorescent (VTF)

#### **Assignment Sheet #3**

1. Speedometer, fuel gauge, temperature gauge, trip odometer and tachometer (w/manual transmission), high beam, fasten safety belts, brake, charge, oil pressure warning indicators
2. Magnetic
3. Two, a speedometer/odometer/tachometer module, and a fuel computer/scanner module which also includes magnetic fuel and temperature gauges, and warning lamps
4. RUN



**ANSWERS TO ASSIGNMENT SHEETS**

5. They momentarily light all the display segments, and then momentarily turn them off
6. By pressing the MPH/km/h button
7. Distance to empty
8. Yes, 85 mph or 136 km/h
9. By blinking the word SPEED, and giving three short beeps
10. Instantaneous fuel economy, average fuel economy, and distance to empty
11. Both (as operator selects)
12. Any three of the following: NORMAL, DOOR AJAR, LIFTGATE AJAR, HEAD LAMP OUT, TAIL LAMP OUT, BRAKE LAMP OUT, and WASHER LEVEL LOW

## AUTOMOTIVE MICROPROCESSOR APPLICATIONS UNIT IX

### TEST

NAME \_\_\_\_\_

SCORE \_\_\_\_\_

1. Match terms related to automotive microprocessor applications with their correct definitions.

- |         |                                                                                                                                                            |                  |
|---------|------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------|
| _____a. | A dashboard-mounted digital readout of vehicle speed and other function gauges such as fuel level, oil pressure, and engine temperature                    | 1. VATS          |
|         |                                                                                                                                                            | 2. EIC           |
|         |                                                                                                                                                            | 3. VSS           |
| _____b. | An electric motor that takes digital input pulses, and converts that signal into a continuous sweeping output such as a speedometer needle                 | 4. Stepper Motor |
| _____c. | A protection system that disables the ignition system, and eventually the starter system if an incorrect key is used or if a "hot wire" start is attempted |                  |
| _____d. | A digital input signal to the CPU that is used to operate cruise control, speedometer readings, and torque converter lockup systems                        |                  |

2. Select true statements concerning dashboard functions by placing an "X" beside each statement that is true.

- |         |                                                                                                                                                                            |
|---------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| _____a. | In modern vehicles, engines are computer controlled, but computers also operate to enhance operator comfort and alert the operator to trouble.                             |
| _____b. | The most noticeable change in contemporary vehicle dashboards is the EIC which uses bar graph representations and digital numerics where analog gauges were previous used. |
| _____c. | For eye appeal and reading ease, EIC bar graphs are lit by LEDs or by fluorescent back-lighting techniques.                                                                |
| _____d. | EIC operations are also aided by the CPU which supplies vehicle speed information to the VSS buffer.                                                                       |
| _____e. | The VSS buffer transmits data to the EIC so MPH can be determined and properly displayed.                                                                                  |

## TEST

- \_\_\_\_f. When systems use an electric analog speedometer, the conventional sweep needle is driven by conventional mechanical devices.
- \_\_\_\_g. Almost all EICs contain a warning light to alert the operator to problems with the CPU system.
- \_\_\_\_h. Some systems have maintenance reminder indicators that alert the operator to the need for service.
3. Complete statements concerning anti-lock brake controls by circling the word(s) that best complete(s) each statement.
- There are several different types of anti-lock brake controls, and all of them use **(some degree of, complete)** CPU control.
  - Most systems have a wheel speed indicator constructed of a simple slip ring and an interruptor system that works with a **(magnetic field, digital device)** located periodically to send an impulse to the sensor.
  - When the wheel stops turning, the signal to the sensor is interrupted, and the brake fluid pressure to the disc caliper is **(pulsed, stopped)** until the wheel sensor indicates motion once again.
  - Some light duty trucks use a **(front, rear)** wheel anti-lock brake system.
  - Some advanced systems use a modification of the anti-lock brake system to control **(lock-up, wheel slippage)** during acceleration, and this requires a complicated power train with variable torque capabilities.
4. Solve problems concerning seat position controls by answering the following questions.
- What is the name of the device that has solved the problem of seat adjustment for vehicles driven by more than one person?  
Answer: \_\_\_\_\_
  - What problem does the adjustment device eliminate for an operator?  
Answer: \_\_\_\_\_
5. Solve problems concerning electronic steering controls by answering the following questions.
- How does a steering system that uses all four wheels to steer a vehicle improve tire wear?  
Answer: \_\_\_\_\_

## TEST

- b. How does four-wheel steering eliminate the problem of two different turning radii-uses?

Answer: \_\_\_\_\_

6. Select true statements concerning suspension controls by placing an "X" beside each statement that is true.

- \_\_\_\_\_a. Many vehicles use suspension height devices that are filled or vented by small compressors that are controlled by a computer.
- \_\_\_\_\_b. Height sensors mounted on the frame of the vehicle monitor chassis position; if the body is low, the computer energizes the compressors, and air is pumped into the shocks to raise the body.
- \_\_\_\_\_c. When the body is riding too high, the compressors vent pressure from the shocks in order to lower the body.
- \_\_\_\_\_d. Drivers can control ride quality in some systems through driver-selected controls that change hydraulic valving characteristics in suspension support devices to make the ride more firm or softer.

7. Solve problems concerning keyless entry by answering the following questions.

- a. Some keyless entry systems require an operator to dial certain numbers to gain entry; what could this be compared to?

Answer: \_\_\_\_\_

- b. In cases where the entry system is disabled for a length of time after an unsuccessful number of attempts to gain entry, what has probably been accomplished other than to deter theft?

Answer: \_\_\_\_\_

8. Select true statements concerning theft deterrent systems by placing an "X" beside each statement that is true.

- \_\_\_\_\_a. There are many different theft deterrent systems in the contemporary vehicles, but the most successful is the VATS used on late model Corvettes.
- \_\_\_\_\_b. The VATS uses a resistor in the shank of the ignition key, and if the VATS module doesn't read the proper resistance, the ignition system is disabled, and there will be no secondary ignition to the spark plugs.
- \_\_\_\_\_c. If repeated attempts to start the car are made, the VATS module will honk the horn and blink the lights.

## TEST

- \_\_\_\_\_d. Some entry deterrent systems are activated when the door jamb switch indicates an open door, and an alarm not properly reset; the horn sounds in repeated, short blasts, and the headlights flash on and off rapidly.
- \_\_\_\_\_e. Other anti-theft systems use a motion detector such as a liquid mercury switch that closes the alarm circuit when the vehicle is bumped or moved.
9. Solve problems concerning trip control/monitor systems by answering the following questions.
- a. In a trip monitor, what happens to the expected time of arrival if (1) vehicle speed decreases, and (2) vehicle speed increases?
- Answer: \_\_\_\_\_
- b. In addition to average fuel economy, average MPG, and ETA, what other important information do some monitor systems provide an operator?
- Answer: \_\_\_\_\_
10. Complete statements concerning cruise control by circling the word(s) that best complete(s) each statement.
- a. Most of the cruise control systems after 1984 are controlled by a computer, and are much more durable and reliable than the older (**transducer, cable**) systems.
- b. The cruise control computer is tied into the (**EGR, VSS**) circuits of the CPU, and determines the amount of vacuum to be applied to the vacuum servo.
- c. The vacuum servo is attached to the throttle linkage, and opens and closes the throttle in varying amounts depending on the (**vacuum applied, engine temperature**).
- d. Some cruise control systems allow the operator to control vehicle speed in increments of (**1 mph, 1/2 mph**).
11. Select true statements concerning electronic climate control by placing an "X" beside each statement that is true.
- \_\_\_\_\_a. Instead of using mechanical devices to control air blending and distribution, many vehicles now use an electronic control module for the heater/air conditioning systems.
- \_\_\_\_\_b. Some systems use electrically controlled vacuum solenoids to add or bleed vacuum at various servos which control air output.
- \_\_\_\_\_c. The computer also controls air conditioning compressor cycling, and it is often tied into the CPU which can disable the A/C under wide open throttle operation.

## TEST

- \_\_\_\_\_d. The CPU cannot disable the A/C compressor during engine overheating to help reduce heat at the radiator.
  - \_\_\_\_\_e. Some electronic systems still use a temperature lever for operator selection of passenger compartment temperature, but the lever is attached to a variable resistor or similar electronic device for computer input.
  - \_\_\_\_\_f. Fully automatic climate control systems use an inside temperature sensing device to provide feedback to the computer so that fine tuning of temperature goes on every 20 minutes.
12. Solve problems concerning voice alert systems by answering the following questions.
- a. What happens to a spoken alert when the radio speaker is playing loud music?  
Answer: \_\_\_\_\_
  - b. If a car is being exported, in what language would the voice alert system be?  
Answer: \_\_\_\_\_
  - c. What choice does an operator have about the type of voice that delivers the alert messages?  
Answer: \_\_\_\_\_
13. Solve problems concerning other control systems by answering the following questions.
- a. What out-of-vehicle device is used in guidance systems that identify a vehicle's location?  
Answer: \_\_\_\_\_
  - b. In a sophisticated guidance system, how can an operator pinpoint immediate, observable landmarks?  
Answer: \_\_\_\_\_
  - c. How has Doppler radar been used by one manufacturer as a control system?  
Answer: \_\_\_\_\_
- (NOTE: If the following activities have not been accomplished prior to the test, ask your instructor when they should be completed.)
- 14. Identify Chrysler computer applications for operator comfort and safety. (Assignment Sheet #2)
  - 15. Identify General Motors computer applications for operator comfort and safety. (Assignment Sheet #2)
  - 16. Identify Ford computer applications for operator comfort and safety. (Assignment Sheet #3)

## AUTOMOTIVE MICROPROCESSOR APPLICATIONS UNIT IX

### ANSWERS TO TEST

1.   a.    2  
     b.    4  
     c.    1  
     d.    3
2.   a, b, c, d, e, g, h
3.   a.    Some degree of  
     b.    Magnetic field  
     c.    Pulsed  
     d.    Rear  
     e.    Wheel slippage
4.   a.    The memory seat  
     b.    Trial-and-error adjustments
5.   a.    By reducing turning radius  
     b.    By aiming the rear wheels in the track of the front wheels
6.   a, b, c, d
7.   a.    A combination lock  
     b.    Helped keep a few impaired drivers off the road
8.   a, b, d, e
9.   a.    (1) The ETA increases (2) The ETA decreases  
     b.    The distance the operator can drive before running out of gas
10.  a.    Transducer  
     b.    VSS  
     c.    Vacuum applied  
     d.    1 mph
11.  a, b, c, e

**ANSWERS TO TEST**

- 12.
  - a. It mutes the radio so the message can be heard
  - b. In the language of the country of destination
  - c. Male or female
  
- 13.
  - a. A satellite
  - b. With an area map
  - c. To warn the operator of a collision
  
- 14. Assignment Sheet #1 evaluated to the satisfaction of the instructor
  
- 15. Assignment Sheet #2 evaluated to the satisfaction of the instructor
  
- 16. Assignment Sheet #3 evaluated to the satisfaction of the instructor